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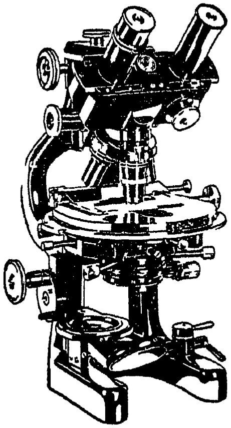

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THE

SOUTH AFRICAN JOURNAL OF SCIENCE

VOLUME XXXVII

BEING THE

REPORT

OF THE

THIRTY-EIGHTH ANNUAL MEETING

OF THE

SOUTH AFRICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

JOHANNESBURG

1940

1st. and 2nd July

JOHANNESBURG:
PUBLISHED BY THE ASSOCIATION
and
Printed by SAMUEL GRIFFITHS AND CO., LTD. Dock Road,
Cape Town.

1941.

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for the Advancement of Science
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   (Note.—Academic qualifications, etc., are not indispensable.)
   ....
3. Profession or Occupation ....
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THE

SOUTH AFRICAN JOURNAL OF SCIENCE

BEING THE REPORT OF THE

SOUTH AFRICAN ASSOCIATION FOR THE
ADVANCEMENT OF SCIENCE

(1940, JOHANNESBURG.)

Vol. XXXVII. FEBRUARY, 1941. Vol. XXXVII.

EDITORIAL NOTE.

Owing to the claims of national duties upon the Hon. Editor of Publications, Prof. John Phillips, I have been privileged to see this volume through the press, and I am deeply indebted to him for constant help and guidance in that task.

My sincere thanks are also due to Professors L. F. Maingard and H. H. Paine for their kindly assistance, and also to many authors for their generous co-operation in the reduction and modification of their papers and for the early return of proofs.

S. A. Asher

Hon. Associate Editor.

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PROCEEDINGS OF THE THIRTY-EIGHTH ANNUAL GENERAL MEETING OF MEMBERS, HELD AT KELVIN HOUSE, JOHANNESBURG, ON TUESDAY. 2ND JULY, 1940, AT 12-15 P.M.

PRESENT: Professor C. G. S. de Villiers (President) (in the Chair), Mr. S. B. Asher, Dr. M. G. Breyer-Brandwijk, Mr. H. B. S. Cooke, Professor R. A. Dart, Mr. H. H. Dodds, Dr. A. L. du Toit, Mr. C. Ferguson, Dr. J. Gillman, Mr. Jas. Gray, Mr. T. D. Hall, Dr. G. N. G. Hamilton, Mr. J. Harcus, Professor P. R. Kirby, Dr. F. E. T. Krause, Professor L. F. Maingard, Mr. B. D. Malan, Mr. D. B. D. Meredith, Dr. M. G. Mes, Mr. E. T. Meyer, Dr. F. T. Milne, Miss J. M. Murray, Professor John Orr, Dr. N. F. Paterson, Mr. F. R. Paver, Dr. E. Percy Phillips. Professor John Phillips, Professor F. E. Plummer, Dr. Austin Roberts, Professor G. H. Stanley, Professor G. A. Watermeyer, Dr. H. Weinmann, Dr. L. H. Wells, Dr. H. E. Wood (Honorary General Secretary) and Mr. A. J. Adams, (Assistant General Secretary).

Apologies for absence were received from Mr. P. Freer, Dr. E. J. Hamlin, Mr. A. J. Limebeer, Professor I. D. MacCrone, Professor H. H. Paine, Mr. J. H. Power, Dr. J. B. Robertson, Dr. B. Segal and Professor C. van Riet Lowe.

MINUTES: The Minutes of the Thirty-Seventh Annual General Meeting, held at East London, on the 7th July, 1939, and printed on pages iii to v of the Report of the East London Session, (Volume XXXVI of the JOURNAL), were confirmed.

ANNUAL REPORT OF COUNCIL: The Annual Report of the Council for the year ending 30th June, 1940, having been duly suspended on the Notice Board, was taken as read and adopted. This report will be found on pages vi, vii, viii, of this volume.

REPORT OF THE HONONARY GENERAL TREASURER AND STATEMENT OF ACCOUNTS.—The Honorary General Treasurer's Report and Statement of Accounts for the year ended 31st May, 1940, having been duly displayed on the Notice Board, were taken as read and adopted. (See pp. ix—xv of this volume.)

ELECTION OF OFFICERS FOR 1940-1941.—The following were elected:

President: Mr. Jas. Gray.

Vice-Presidents: Dr. A. Pijper.
Professor M. M. Rindl.
Col. J. G. Rose.
Mr. J. F. Schofield.

Hon. General Secretaries: Dr. C. F. Juritz and Dr. H. E. Wood.
Hon. General Treasurer: Mr. Jas. Gray.
Hon. Editor of Publications: Professor John Phillips.
Hon. Librarian: Mr. P. Freer.

COUNCIL MEMBERS.—The following were elected:—

1. TRANSVAAL.—Mr. S. B. Asher, Mr. R. Craib, Professor R. A. Dart, Mr. T. D Hall, Dr. E. J. Hamlin, Professor P. R. Kirby, Mr. A. J. Limebeer, Professor I. D. MacCrone, Professor L. F. Maingard,

Professor John Orr, Professor H. H. Paine, Mr. F. R. Paver, Dr. J. B. Robertson, Professor G. H. Stanley, Professor C. van Riet Lowe, Dr. R. Broom, Dr. P. J. du Toit, Dr. F. E. T. Krause, Dr. R. H. Marloth, Dr. R. J. Ortlepp, Dr. E. Percy Phillips, Dr. E. M. Robinson, Professor A. P. Goossens.

II. Cape of Good Hope Province.—Dr. L. Boonstra, Colonel C. Graham Botha, Dr. A. J. Hesse, Mr. G. W. Lyon, Dr. B. de C. Marchand, Dr. S. H. Skaife, Mr. F. J. S. Anders, Mr. G. O. Neser, Professor L. Verwoerd, Mr. J. H. Power, Professor N. J. G. Smith, Dr. M. Boehmke, Dr. P. W. Laidler.

III. Orange Free State.—Dr. W. J. Lutjeharms, Dr. E. C. N. van Hoepen.

IV. Natal.—Professor A. W. Bayer, Dr. S. F. Bush, Dr. R. F. Lawrence, Mr. E. C. Chubb, Mr. H. H. Dodds, Dr. A. McMartin.

V. Southern Rhodesia.—Mr. H. B.Maufe.

Amendments to the Constitution and By-Laws.—The President moved the adoption of the following amendments to the Constitution and By-Laws, which had been approved by the Council in accordance with the provisions of Section 40 of the Constitution:—

Constitution.

Section 24.—Add "together with the Secretary and Treasurer of the Local Committee."

Section 36.—Delete "Such Disbursements . . ." to end of section.

By-Laws.

Section 6.—Omit "Degrees." Add "Papers should not be more than 5,000 words in length."

Section 15.—Add "The delivery of Presidential Addresses should not occupy more than one hour."

Section 32.—Delete; and Substitute: "A Local Committee should be constituted for the centre at which the Annual Session is to be held, at least six months in advance thereof. The composition of this Committee will be at the discretion of the local civic authorities, but should include regular members of the Association resident in the neighbourhood, and representatives of the municipality and of leading local societies and institutions."

Section 33.—Delete; and substitute: "The Local Committee shall appoint a Local Secretary and Local Treasurer, an Executive Committee and such sub-committees as may be desirable, to make arrangements for the reception and entertainment ot visitors."

Section 34.—Add "local" between "all" and "expenses."

On the proposal of Professor R. A. Dart, seconded by Dr. F. E. T. Krause, the above amendments were carried by the Meeting.

Annual Meeting, 1941.—It was reported that two invitations had been received, namely from the Municipalities of Oudtshoorn and Kingwilliamstown. On being put to the meeting, the invitation for the Association to hold its Annual Session in Oudtshoorn in 1941 was accepted.

Annual Meeting: Suspension.—In view of the international situation, it was agreed that the Council have power to suspend the holding of an Annual Meeting next year if it is deemed expedient to do so.

Votes of Thanks.—On the proposal of Mr. T. D. Hall, it was agreed unanimously that the thanks of the Association be accorded to the Associated Scientific and Technical Societies of South Africa for providing the necessary accommodation for the holding of the Annual Session in Kelvin House, and to the Press for their services in reporting the proceedings of the Session.

Mr. Jas. Gray proposed a hearty vote of thanks to the President for the able manner in which he had conducted the Johannesburg Session, which had proved most satisfactory. In replying to the vote of thanks, the President expressed his appreciation to Mr. Gray for deputising for him at meetings during his year of office and to the Council for their loyal support.

This concluded the business, and the meeting terminated at 12-45 p.m.

REPORT OF COUNCIL FOR THE YEAR ENDING 30TH JUNE, 1940.

1. Obituary.—Your Council reports with regret the deaths of the following members:— Dr. F. E. Crinsoz de Cottens, Mr. T. Douglas, Sir Spencer Lister (South African Medallist, 1921), Mr. T. S. McEwan (Foundation Member), Right Rev. Dr. Hugh MacSherry, Mr. A. M. Neilson, Mr. C. W. Pearsall (Life Member), Dr. S. Schonland (President of Section C, 1908, Foundation Member).

2. Membership.—Since the last Report twenty-six members have joined the Association, eight have died, and fifty-four have resigned.

The following table shows the geographical distribution of membership as at the 30th June, 1940:

Transvaal	346
Cape of Good Hope Province	183
Natal	89
Orange Free State	29
Southern and Northern Rhodesia	13
South-West Africa	2
Moçambique	5
Abroad	27
	694

3. The Journal.—Volume XXXVI of the *South African Journal of Science*, comprising the report of the East London Meeting, consisted of 578 pages, one plate and numerous text figures. It was published in May, 1940.

4. The South Africa Medal and Grant.—On the recommendation of the South Africa Medal Committee consisting of Dr. H. E. Wood (Chairman), Professor A. W. Bayer, Professor P. R. Kirby, Professor I. D. MacCrone, Professor L. F. Maingard, Dr. B. de C. Marchand, Dr. E. P. Phillips, Professor M. M. Rindl, Professor B. F. J. Schonland, Dr. A. L. du Toit, Dr. P. J. du Toit and Professor C. G. S. de Villiers, your Council has awarded the South Africa Medal, together with a grant of £59:9:4., to Dr. Austin Roberts. The Secretary of the British Association has been notified of the award.

5. The British Association Medal.—Five papers were submitted at the Annual General Meeting in July, 1939, in competition for the award of the British Association Medal. Three of these papers, which were judged to be of the highest merit, were forwarded to the British Association for final adjudication by the Council of that Association. Your Council has been informed that it has been decided by the Council of the British Association that the eighth award of the Medal shall be made to Dr. J. H. L. Cloete for his paper entitled "The Estimation of the Age of Merino Foetuses."

6. Donations.—The thanks of the Association are due to the Honourable the Minister of Mines, Education, Labour and Social Welfare for a grant of £250 towards the expenses of the publication of the Journal.

7. QUARTERLY BULLETINS.—Three Bulletins have been issued during the year under review, No. 1. in March, 1940; No. 2 in April, 1940; and No. 3 in June, 1940. The scope and nature of the Bulletins have been discussed by the Council and it was decided that it was desirable that they should continue in the form of a Scientific "Newsletter" to members of the Association and that they should be published at fixed times. Mr. S. B. Asher has been appointed Associate Editor, and has assisted the Editor in the publication ot the 1940 Bulletins.

8. POLICY OF THE ASSOCIATION.—The Council has had under consideration the question of the use of the two official languages of the Union in its proceedings. The Council agrees that both official languages shall receive equal recognition and that this principle shall be given practical effect as far as the financial position of the Association allows.

9. RESTORATION OF FORT MURRAY.—Following upon a resolution passed by the Annual General Meeting at East London on the 7th July, 1939, urging that steps should be taken to preserve the remains of Fort Murray, a comprehensive report was prepared by Mr. J. F. Schofield on the subject. This report was sent to the Historical Monuments Commission and also to the Municipalities of Kingwilliamstown and East London.

10. ANNUAL MEETING 1940.—It had been decided at the Annual General Meeting at East London to accept the invitation of the Municipality of Salisbury, Southern Rhodesia, to hold the Thirty-Eighth Annual Meeting of the Association at Salisbury from the 10th to the 16th July, 1940, and that the meeting should take the form of a joint meeting with the Rhodesia Scientific Association. Complete arrangements for the holding of this joint meeting were drawn up, but on the 3rd June, the Rhodesia Scientific Association recommended that in view of the difficult situation the holding of the meeting should be postponed. At a special meeting of the Council held on the 6th June it was accordingly decided to postpone the holding of a meeting at Salisbury. The Salisbury Municipality was therefore advised that their invitation to the Association could not be accepted this year, and it was hoped that the invitation might be repeated at a later time.

In view of the necessity for the holding of an Annual Meeting in accordance with Clause 18 of the Constitution and By-Laws, it was decided that the Thirty-Eighth Annual Meeting should be held at Johannesburg on the 1st and 2nd July, 1940.

11. THE NEW COUNCIL.—On the basis of Membership provided in the Constitution, Section 22, the numbers of members of Council assigned for the representation of each Centre during the ensuing twelve months should be distributed as follows:—

Transvaal—

Witwatersrand	15
Pretoria	7
Outside	1

Cape of Good Hope Province—	
Cape Peninsula and Outside	6
Stellenbosch and District	2
East London and Port Elizabeth ...	1
Grahamstown, Kingwilliamstown and District	1
Kimberley	1
Oudtshoorn	1
Outside	1
Natal—	
Durban	3
Pietermaritzburg and Outside Districts	3
Orange Free State—	
Bloemfontein	2
Southern Rhodesia	1
	45

12. SECRETARIAT.—On the 30th September, 1939, Mr. H. A. G. Jeffreys, O.B.E., retired on superannuation from the position of Assistant General Secretary. At a subsequent meeting of the Council a presentation was made to Mr. Jeffreys on behalf of the members of the Association. Officers of the Association expressed their appreciation of the valued services rendered by Mr. Jeffreys during the past nineteen years. At the meeting of Council held on 20th October, 1939, Mr. Jeffreys was elected an Honorary Life Member of the Association.

The Council is pleased to report that it has been able to make some financial provision for Mr. Jeffreys in the form of a monthly allowance in recognition of his services.

The Associated Scientific and Technical Societies of South Africa have undertaken the secretarial work of the Association as from the 1st October, 1939.

REPORT OF THE HONORARY GENERAL TREASURER FOR THE YEAR ENDED 31st MAY, 1940.

As Members are aware, the Editor and his Committee have been endeavouring for several years to reduce the cost of publication of the South African Journal of Science to a figure more in accordance with the income of the Association. Notwithstanding their efforts in this direction, this year's publication cost £83 more than last year. However, owing to a better response by members in paying their subscriptions, the income of the Association has increased by approximately £200. A gratifying feature has been that the receipts from arrear subscriptions is greater by £173 than it was last year.

An additional item of expenditure has been the payment of a small pension to Mr. H. A. G. Jeffreys, who retired towards the end of last year, after many years devoted service to the Association, as Assistant General Secretary.

The final result of the year's working shows an excess of expenditure over revenue of £34 14 2, a result which can be considered moderately satisfactory.

The Council regrets that the financial position has rendered it necessary to restrict the size of the Journal. It desires to place on record its grateful thanks to those authors who have assisted towards the cost of publication of their contributions.

JAS. GRAY,

Honorary General Treasurer.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

BALANCE SHEET AT 31st MAY, 1940.

LIABILITIES.

Sundry Creditors—						
General Accounts	£975	3	1			
Witwatersrand Local Centre	237	10	4			
Endowment Fund	12	9	6			
South Africa Medal Fund	55	16	6			
British Association Medal Fund	29	15	3			
Library Deposits	3	0	0			
Subscriptions paid in advance	18	10	0			
				£1,332	4	8
Library Binding and Equipment Account						
Balance at 31st May, 1939	110	0	11			
Add—Interest on Library Endowment Fund	76	6	6			
	186	7	5			
Less—Expenditure during year	92	5	1			
				94	2	4
Revenue and Expenditure Account—						
Balance at 31st May, 1939	124	13	5			
Less—Excess of Expenditure over Revenue for the year ended 31st May, 1940	32	14	2			
				91	19	3
				1,518	6	3
Endowment Fund				3,122	14	5
Library Endowment Fund				2,164	11	6
South Africa Medal Fund				1,617	16	3
British Association Medal Fund				479	15	3
				£8,903	3	8

ASSETS.

Cash—						
At Bank	£545	7	0			
At Post Office Savings Bank, with interest accrued	36	3	10			
At St. Andrew's Building Society, with interest accrued	801	19	1			
				£1,383	9	11
Sundry Debtors—						
For Advertisements in Journal				62	15	0
Payments in Advance				0	15	0
Furniture				66	7	6
Medals on Hand				4	18	10
				1,518	6	3
Trustees' Endowment Fund—						
As per separate account				3,122	14	5
Library Endowment Fund—						
As per separate account				2,164	11	6
Trustees—South Africa Medal Fund—						
As per separate account				1,617	16	3
Trustees—British Association Medal Fund—						
As per separate account				479	15	3
				£8,903	3	8

We have examined the books and vouchers of the South African Association for the Advancement of Science for the year ended 31st May, 1940, and certify that in our opinion the above Balance Sheet correctly sets forth the position of the Association at the 31st May, 1940, according to the best of our information and the explanations given to us as shown by the books.

JOHANNESBURG.
28th June, 1940.

ALEX AIKEN & CARTER,
Auditors.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1940.

Dr.

To Salaries and Secretarial Fees			£195 0 0
,, Rent			21 0 0
,, Journal Expenses		982 14 5	
Less—			
Government Grant	£250 0 0		
Sales, Reprints & Advertisements .	108 8 3		
		358 8 3	
			624 6 2
,, Printing and Stationery ...			49 14 9
,, Stamps and Telegrams ...			16 6 8
,, Insurance—Fidelity Bond and Workmen's Compensation ...			4 11 6
,, Expenses — Annual Meeting, 1939 (balance)		30 1 6	
,, Expenses — Annual Meeting, 1940 (on account)		2 13 2	
			32 14 8
,, Sundry General Expenses .			20 19 1
,,Grants to Local Centres under Rule 35—			
Witwatersrand		32 0 0	
Cape Province		14 3 0	
Natal		9 6 0	
Orange Free State ...		2 2 0	
			57 11 0
,, Depreciation on Office Furniture			10 0 0
,, Pension—H. A. G. Jeffreys ...			52 10 0
			£1,084 14 1

Cr.

By Annual Subscriptions ...	£611 10 0	
,, Arrear Subscriptions	288 10 0	
,, Associates' Fees	2 0 0	
,, Students' Fees	1 1 0	
		903 1 0
,, Interest—		
On Endowment Fund ...	135 13 0	
On St. Andrew's Building Society Account ...	12 8 6	
On Post Office Savings Bank Account	0 17 5	
		148 18 11
,, Balance, being Excess of Expenditure over Revenue for year ended 31st May, 1940		32 14 2
		£1,084 14 1

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

ENDOWMENT FUND.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1940.

Dr.

	£	s.	d.
To Interest, as per contract, transferred to General Fund	£135	13	0
,, Balance transferred to Accumulated Funds	37	10	0
	£173	3	0

Cr.

	£	s.	d.
By Interest received during the year	£135	13	0
,, Life Membership Subscriptions . ..	37	10	0
	£173	3	0

BALANCE SHEET AT 31st MAY, 1940.

Liabilities.

	£	s.	d.	£	s.	d.
Accumulated Funds—						
Balance at 31st May, 1939 ...	£3,085	4	5			
Add—Amount transferred from Revenue and Expenditure Account	37	10	0			
				3,122	14	5
				£3,122	14	5

Assets.

	£	s.	d.	£	s.	d.
Investments in hands of Trustees—						
Cape Town Municipality 3¾% Stock	£1.150	0	0			
Cape Town Municipality 4% Stock	300	0	0			
Cape Town Municipality 5% Stock	240	0	0			
Cape Town Municipality 5% Stock	800	0	0			
Port Elizabeth Municipality 3½% Stock	100	0	0			
Cape of Good Hope Savings Bank	520	4	11			
				3.110	4	11
Amount due from General Fund				12	9	6
				£3.122	14	5

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

LIBRARY ENDOWMENT FUND.

Dr. REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1940. Cr.

	£	s.	d.		£	s.	d.
To Balance transferred to Library Binding and Equipment Account	£76	6	6	By Interest received during the year	£76	6	6
	£76	6	6		£76	6	6

BALANCE SHEET AT 31st MAY, 1940.

Liabilities.	£	s.	d.	Assets.	£	s.	d.
Accumulated Funds—				Investments—			
Balance at 31st May, 1939	£2,164	11	6	£2,000 City of Johannesburg 3½% Local Registered Stock—At Cost	£1,970	0	0
				Cash at St. Andrew's Building Society—Savings Bank Account	194	11	6
	£2,164	11	6		£2,164	11	6

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

SOUTH AFRICA MEDAL FUND.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1940.

Dr.		Cr.	
To Expenses in connection with 1940 Award	£6 1 1	By Interest received during the year	£65 10 5
,, Amount of Award, 1940	59 9 4		
	£65 10 5		£65 10 5

BALANCE SHEET AT 31st MAY, 1940.

LIABILITIES.		ASSETS.	
Sundry Creditors—		Investments in hands of Trustees—	
1940 Award	£59 9 4	Fixed Deposit. South African Permanent Mutual Building and Investment Society	£1.547 15 11
Accumulated Funds—		Post Office Savings Bank	73 13 2
Balance at 31st May. 1939	1.617 16 3	Amount Due from General Fund ..	55 16 6
	£1.677 5 7		£1.677 5 7

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE BRITISH ASSOCIATION MEDAL FUND

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1940

Dr.		**Cr.**	
To Award	£20 0 0	By Interest received during the year	£16 17 6
		" Balance transferred to Accumulated Funds	3 2 6
	£20 0 0		£20 0 0

BALANCE SHEET AT 31st MAY, 1940

LIABILITIES			ASSETS	
Accumulated Funds—			Investments in hands of Trustees—	
Balance at 31st May 1939	£482 17 9		£450 Union of South Africa 3½% Local Registered Stock 1918/58	£450 0 0
Less — Amount transferred from Revenue and Expenditure Account	3 2 6		Amount due from General Fund	29 15 3
		479 15 3		
		£479 15 3		£479 15 3

REPORT OF THE HONORARY LIBRARIAN FOR THE YEAR ENDED 31st, MAY, 1940.

The Association's Library is housed in the Library of the University of the Witwatersrand, Johannesburg.

HOURS OF OPENING ARE AS FOLLOWS:—

Weekdays. Term: 8.30 a.m. to 6 p.m.
Vacation: 9 a.m. to 5 p.m.

Saturdays. Term: 8.30 a.m. to 12.30 p.m.
Vacation: 9 a.m. to 12.30p.m.

EXCHANGE OF PUBLICATIONS.—The name of the *National research council of Japan* has been added to the free mailing list to receive volumes of the *Journal* in return for several publications which were formerly coming gratis. Agreements to exchange publications were concluded with the *Institut für Weltwirtschaft, Kiel,* and the *Kolonial-Wirtschaftliches Komitee, Berlin,* but war broke out before any publications were received. In compliance with a request from the editor of *Annual tables of constants and numerical data,* it was agreed to send two free copies of the Journal for systematic tabulation of numerical data. The work of this organisation, however, has now probably been suspended.

DONATIONS.—Gifts other than exchange material have been received from the following:—

British Museum (Natural History).—*Economic series No. 1. The House Fly; 4th ed. John Murray expedition. Scientific reports, vol. 5, No. 8. Morellet, L. Tertiary siphoneous algae.*

Mrs. H. A. G. Jeffreys.—*South African Journal of Science. Vols.* 19-35, 1922-38.

National Geographical Society.—*Solar eclipse expedition of* 1937 *to Canton Island.*

Nederlandsche Dierkundige Vereeniging.—*Flora en fauna der Zuiderzee. Supp. De biologie van de Zuiderzee. Afdl.* 1-4.

Dr. A. Porter.—*Porter, A. Larval trematoda of S. African mollusca. Fantham, H. B.* 6 *reprints.*

BINDING.—113 Volumes were bound during the year.

STOCK.—The Library now contains about 3,200 volumes. Owing to the war the supply of journals from the continent has virtually ceased, but over 200 titles are still received currently.

ACCESSIONS TO SERIAL PUBLICATIONS, 1939-40.

For a *Catalogue of serial publications in the Library, and Supplement,* see this JOURNAL, Vol. 30, p. xxv-xxix and Vol. 34, p. xxxiv-xxxvii. Subsequent accessions are given in the Annual reports.

Academy of Natural Sciences of Philadelphia. Notulae Naturae. 1, 1939+.

Advancement of Science. 1, 1939+.

Michigan University. Herbarium Contributions. 1, 1939+

Mozambique. Reparticao de estatistica. Boletim mensal das observacoes meteorologicas. 1, 1934+.

New South Wales. Geological survey. Mineral resources. 37, 1939+.

P. FREER,
Honorary Librarian.

University of the Witwatersrand,
Johannesburg.
21st February, 1941.

In Memoriam.

JOSEPH BURTT DAVY, M.A., (OXON.), DR. PHIL., (OXON.), PH. D. (CANTAB.) F.R.G.S., F.L.S.

Dr. Burtt Davy was born on the 17th March, 1870, at Findern in Derbyshire and died at Oxford on the 20th August, 1940. His name will always be associated with the Transvaal Colonial Herbarium now the National Herbarium.

During the year 1891-92 Burtt Davy was an assistant to the Director of the Royal Botanic Gardens, Kew, but resigned owing to ill-health and went to California where he became a research worker at Berkeley University and subsequently held various botanical posts, among which was that of assistant curator in the U.S. Department of Agriculture at Washington. During his stay in the United States Burtt Davy wrote a number of papers on the vegetation of various parts of the country, including those on "The Stock Ranges of Northwestern California," and on "The Native Vegetation and Crops of the Colorado Delta in the Salton Basin." He also wrote the section on the Gramineae for Jepson's "Flora of the Western Middle California."

His connection with South Africa began in May, 1903, when he was appointed Agrostologist and Botanist in the newly formed Transvaal Department of Agriculture, the first State Agricultural Organisation in the Transvaal.

In his first annual report he records having placed over 3,300 species in the newly formed Herbarium during that year. Burtt Davy was very interested in the subject of plant introduction and devoted much time to the introduction of seeds and plants from various parts of the world. These were tested out at the various experiment stations. An outstanding success was the introduction of teff as a forage crop. His interest in plants was wide and his publications deal with many branches of botany.

In 1905, Burtt Davy was appointed as expert member of the Committee of the Transvaal Museum and Zoological Gardens to assist in the development of the Herbarium in the Museum and to help with the laying out and planting of the Zoological Gardens. In 1907 he took charge of the South African Productions Exhibition in London, and while overseas he visited Southern Europe and Northern Africa in order to study methods of growing certain warm temperate crops and also to obtain seed of plants that he considered particularly adaptable to Transvaal conditions. He also paid a visit to America to study the advances in the methods of plant breeding with particular reference to maize. While in England he spent some time at the Herbarium of the Royal Botanic Gardens at Kew, studying the types and naming specimens of Transvaal trees. He subsequently published a work on "The Geographical Distribution of the Native Trees of the Transvaal."

In 1908 he was instrumental in establishing a large maize breeding station at Vereeniging. His interest in maize resulted in a comprehensive work published in 1913 under the title "Maize, its History, Cultivation, Handling and Uses," which remained until recently the standard book on the subject in South Africa.

At the time of Union, the Transvaal was the only province that had an organised Division of Botany, and Burtt Davy, as its Chief, became Government Agrostologist and Chief of the Union's Division of Botany. He resigned this post in 1913 in order to engage in the cultivation of farm seeds at Vereeniging.

After the last war he left South Africa for England and settled at Kew where he began his work on "The Flora of the Transvaal and Swaziland." Two volumes of this work have already been published and South African botanists have good reason to regret that the work has remained unfinished. In 1925 he was appointed University Demonstrator in Forestry and Lecturer in Tropical Forest Botany at the Imperial Forestry Institute, Oxford, a post which he retained up to the time of his death.

In the course of his work at Oxford he had trained many students who later filled responsible forestry posts in the Colonial Service, and with their zealous help he was able to build up a large Forestry Herbarium at Oxford, comprising material from every part of the British Empire. While at Oxford he was also a co-editor of the series of publications entitled "The Forest Trees and Timbers of the British Empire," of which the following are of particular interest to South African botanists and foresters:

Some East African Coniferae and Leguminosae.
Fifteen South African High Forest Trees.
Fifteen Uganda Timbers.

Burtt Davy visited the Union in 1929 as a delegate of the Forestry Section of the British Association for the Advancement of Science. He utilised his visit by making a valuable local collection for the enrichment of the Forest Herbarium at Oxford.

No account of Burtt Davy's work would be complete without reference to his wife Mrs. Alice Burtt Davy. This able and gifted American woman whom he married in California, illustrated many of his contributions and reports on Botany.

Burtt Davy became a Life Member of the Association in 1903, was a member of the Council from 1904 to 1919, and was three times Vice-President of the Association, he was elected a member of the Linnean Society in 1903 and became a fellow of the Royal Society of South Africa in 1905. His first contribution to this Journal was made at the 2nd Annual Meeting of the Association in April 1904 with a fifty page monograph on "Alien plants spontaneous in the Transvaal."

Dr. Burtt Davy has left his mark on South African botany and agriculture, and during his residence in the country gave and inspired loyal and devoted service. A former Secretary for Agriculture in one of his annual reports, wrote:

"During the time he was in the Government Service, Mr. Burtt Davy performed an immense amount of most valuable scientific and educational work, and the services he rendered the country, particularly in connection with the popularisation of teff grass, and the assistance and impetus he gave to mealie growing, will always be regarded as landmarks in the history of South African agriculture."

M. D. G.

In Memoriam

EDWARD THOMAS MELLOR, D.Sc., F.G.S.

Dr. Edward Thomas Mellor, the famous mining geologist, was born in Manchester in 1868 and educated at Manchester Grammar School and the Victoria University, where he studied geology under Sir W. Boyd Dawkins, obtaining from the University of London the degree of B.Sc., in 1895 and that of D.Sc. in 1909. For some years he taught biology at Southampton, but in 1901 he came to S. Africa and in 1902 was appointed Senior Geologist to the newly constituted Geological Survey of the Transvaal, and contributed materially to the advancement of the organisation. He became Assistant Director of the Geological Survey of the Union in 1916, though only for a short period, resigning that position to accept the important post of Consulting Geologist to the Central Mining and Investment Corporation, which he held from 1916 until 1930, when he retired from active duties.

During a lengthy career he examined and mapped large tracts in the Transvaal that were scarcely known geologically, mainly in the districts of Potchefstroom, Pretoria, Middelburg, Potgietersrust, Zoutpansberg and Letaba, all regions of definite economic importance. In 1909 he commenced his investigation of the Witwatersrand, which was not completed until 1916.

He was the author of a host of papers, reports and memoirs, official and otherwise, of which the most important were those dealing with the Waterberg Tin Fields. He will, however, best be remembered for his precise studies of the Witwatersrand System and for his clearly presented views regarding the origin of the Rand Gold. His various contributions on the stratigraphy of that system and on the nature and mode of accumulation of the auriferous bankets have proved standards for reference, as has also been his valuable and accurate "Geological map of the Witwatersrand." Marshalling in able fashion the puzzling evidence concerning the bankets, Dr. Mellor found himself drawn to support the "deltaic hypothesis of banket accumulation," a theory favoured since by the majority of geologists. His Work was characterised by a high degree of accuracy, à propos of which, when taxed one day about some small oversight, he retorted, "the errors of omission are less than the errors of commission," a saying which should be taken to heart by every young scientist. This may perhaps explain why, although his profession took him on various occasions into Rhodesia and Central Africa, he remained unwilling to publish anything about those far-flung territories.

One nevertheless feels that Science has been the loser because of such scrupulousness. During later years although professional duties no longer pressed, he proceeded overseas regularly in order to travel with his sons through various parts of Europe. When in Johannesburg, however, few were more regular in their attendance at Council meetings, where his balanced judgment was ever welcome.

Dr. Mellor was a member or a fellow of many learned societies, such as the Geological Society of London, Institute of Mining and Metallurgy, Society of Economic Geologists, Royal Society of S.A., Geological Society of S.A.—of which he was president in 1911—and the S.A. Association for the Advancement of Science—of which he was a sectional president in 1922 and president in 1926. The addresses delivered on those occasions were stimulating and full of interest.

He was awarded the Goldfields Premium by the Institution of Mining and Metallurgy in 1916 and the Draper Memorial Medal by the Geological Society of S.A. in 1939.

Influenced by his early teaching career, he made provision at the University of the Witwatersrand for a Fellowship in Biology, a generous action for which not a few students will some day remember him with gratitude.

As might be surmised of one given to scrutinize scientific details, he was inclined to be rather deliberate in manner, although that did not conceal a whimsical outlook on things.

His death on the 23rd October, 1940, is a great loss to both geological and mining circles and the deepest sympathies of this Association are extended to his widow and sons.

A. L. d. T.

South African Journal of Science, *Vol.*
February, 1941.

COMPARATIVE ANATOMY WITHIN THE FRAMEWORK OF MODERN BIOLOGY

BY

C. G. S. de Villiers,

Professor of Zoology, University of Stellenbosch.
President

Presidential Address delivered 1st July, 1940.

Ladies and Gentlemen; it is expected of the President of the Association that he should render account to its members of the recent advances in his subject or in some branch of that subject in which he has been more particularly interested and upon which he may be expected to speak with some authority. The President is placed in the invidious position of having to deliver an address which shall conform to academic standards, but in which the author shall avoid as far as possible the professional clichés which many intelligent people find so irritating.

There has of late years been a distinct reaction against abstruseness for abstruseness' sake and against the ponderousness of scientific style; a fetish against which Goethe found it necessary to utter a warning. "Die Deutschen," he says, "und sie nicht allein, besitzen die Gabe, die Wissenschaften unzugänglich zu machen " *(Zur Morphologie, 1822)*. I hope I shall put into practice the injunction reiteratedly imposed on young workers trained by me, to say what one has to say in words as few and as simple as possible. The ideal may not prove to be practicable, but in that case it will be through no fault of mine.

I wish to speak to you about the position of Comparative Anatomy within the framework of modern biological science. For in South Africa comparative anatomy is not taught in the medical schools as in Germany and the European Continent generally, but in the Zoological Institutes of our Universities and Colleges. My own interests are more anatomical. although as a university professor in zoology I am supposed to be equally proficient in all the branches of this highly differentiated science.

The history of every science shows definite culminating points, and it is very clear to all who are professional comparative anatomists that in their science such a culminating point has been reached: some biologists even speak of a *crisis*. The publication of the encyclopaedic work on comparative anatomy under the editorship of Bolk, Lubosch, Göppert, Kallius, with the collaboration of a host of other specialists (Urban and Schwarzenberg, Berlin and Vienna) is perhaps symptomatic of the whole position. Let me quote Goethe again:

> "Zur Verewigung des Irrtums tragen die Werke besonders bei, die encyklopädisch das Wahre und Falsche des Tages überliefern. Hier kann die Wissenschaft nicht bearbeitet werden, sondern was man weiss, glaubt, wähnt wird aufgenommen; deswegen sehen solche Werke nach fünfzig Jahren gar wunderlich aus," (*Zur Morphologie*, 1822).

Many as are unquestionably the disadvantages of these collective works, they are nevertheless the indispensable apparatus of the specialist. However that may be, the appearance and conclusion of the great work is proof that comparative anatomy has arrived at the crossways, and that the collective researches of workers since the appearance of Cuvier's "*Leçons d'anatomie comparée*" (1799-1805) are being epitomized.

It is a deplorable fact that the great line of comparative anatomists of the nineteenth century is practically extinct: I am referring to the generation which represented the rich inheritance of Gegenbaur, Goethe, Gaupp and Fürbringer in Germany, Huxley and W. K. Parker in England and Lang in Switzerland. Comparative anatomy has recently sustained an irreparable loss through the deaths of Sewertzoff of Moscow, Lubosch of Würzburg, Böker of Jena and Versluijs of Vienna. The latter was well-known to members of this Association, as he and Prof. Abel were our Viennese guests when the British Association for the Advancement of Science last met in South Africa. The loss of Prof. Versluijs is a particularly severe one, for not only was he a scientist of the highest international distinction, but by virtue of his comprehensive perspective of the science and of his extraordinary pedagogic gifts, he was particularly successful as a writer of textbooks. His work on comparative anatomy is a worthy successor to those of Stannius and of Gegenbaur himself (perhaps I might be permitted at this juncture to deplore the non-existence in the English language of a modern textbook on the lines of Versluijs' famous work). There is in our time no comparative anatomist with the extraordinary perspective of a Gegenbaur or even of a Wiedersheim. It is not my intention to discuss the merits of my colleagues in different parts of the world; one may be permitted the liberty of varying the old Latin dictum into *de viventibus nil nisi bonum.* It is nevertheless necessary for the purposes of this address to examine the reserve forces of the science under discussion.

Many of the German workers are no longer young, and although "old age hath still its honour and its charm," no one could reasonably expect that the productivity of workers like Professors Peters and Matthes of Greifswald and Prof. Fuchs of Göttingen should not show signs of decline in volume. Prof. H. Marcus, formerly of Munich, is no longer attached to a university, Prof. Hescheler of Zurich has constantly had to struggle with failing health and even Prof. Goodrich of Oxford will probably not deny being no longer as young as he was.

In Dr. de Beer of London, Prof. Stadtmüller of Göttingen, Prof. Fahrenholz of Berlin and Prof. Steiner of Zurich, Europe possesses four comparative anatomists in the plenitude of their powers and likely to carry on research in *le grand style.* In France excellent work is being done by Augier and Anthony, but I do not profess to possess very intimate knowledge of the activities of my French colleagues.

I am in a better position to speak from first hand knowledge of conditions in the Italian universities which have been participating fully in the national cultural rejuvenation. But in Italy, as in Germany, comparative anatomy is considered an auxiliary science to medicine, and the younger men like Guareschi, Spirito, and Stefanelli of Rome are working along experimental lines like their colleagues in Munich and the United States, whilst others are more interested in problems of comparative histology and histogenesis. In England biological research tends more and more to focus upon physiological problems. It is symptomatic that the B Series of the Royal Society with its rich anatomical heritage is becoming a physiological journal in all but name.

It would appear from the above that comparative anatomy as a discipline is under a cloud, and the irreverent would possibly not hesitate to use the deprecatory French epithets of *vieux jeu* or *démodé.* Radl in the recently published English edition of his *Geschichte der biologischen*

Theorien ascribes the decline of comparative anatomy to the capriciousness of scientific fashion, as a result of which physiology appears to be momentarily ousting anatomy. Canella in his extremely thoughtful work *L'Anatomia comparata nel quadro della biologia moderna* has drunk deeply of the poison distilled by Labbé and Vialleton and ascribes the decline of comparative anatomy to what is termed the crisis in Darwinism, by which is meant nothing more or less than a disbelief in the phylogenetic basis of comparative anatomy and comparative embryology. I am not acquainted with a single English or German biologist of repute who denies the fact of transformation of species, although there is notoriously much difference of opinion regarding the method or process of such transformation. If, as Vialleton would have us believe, comparative anatomical research on adults and developmental stages can shed no light upon the interrelationship of animals, then indeed Geoffroy St.-Hilaire, Gegenbaur and Haeckel have wasted their lives, and we might revert to the days of Cuvier and Owen. But we should not be prepared to accept it on the word of Vialleton. I don't think that the anatomist or the embryologist or even the palaeontologist can ever prove evolution to have taken place, for a proof needs to be of an experimental nature. But can we reasonably expect to prove experimentally processes that have taken place millions of years ago? Goethe warned us at the beginning of last century that "vieles ist wahr, was sich nicht bis zum entschiedenen Experiment bringen lässt." (*Makariens Archiv*, 1819).

When evolutionists disagree about the way transformation of species has been effected, it is always safest to rely upon the evidence palaeontologists have brought and are bringing forward, as the geological record is being completed, and as new discoveries of important fossil groups like the Ostracoderms (Stensiö, Kiaer and Heintz) are shedding new light upon the early evolution of the Vertebrates.

Palaeontologists like Abel, Watson, Broom, Romer and Gregory will not take anyone seriously who speaks of a crisis in Darwinism implying therewith a crisis in the belief in transmutability of species. Palaeontologists are gradually bridging over the gaps in the evolutionary chain; gaps whose existence some critics used to revel in. Watson's work has vastly contributed towards the elucidation of the problem of the emergence of a terrestrial vertebrate fauna, and the evolution of reptiles and mammals has been solved to the satisfaction of all possessing the Shakespearean "cool reason." Although the evolution of birds from the Jurassic to the Cretaceous is still a vexed question, there cannot be any doubt that they are closely allied to the diapsid *Formenkreis* among the reptiles.

Comparative anatomy is indispensable to the palaeontologist, and all the famous workers mentioned above are first rate anatomists, since the work of the palaeontologist is essentially a comparison of the anatomy of fossil with that of living forms, with a view to obtaining as complete a picture as possible of the phylogeny of the group investigated. On the other hand, the modern anatomist who would venture to leave out of consideration the conditions obtaining in fossil forms would not be taken seriously and would hardly find a scientific journal of repute to accept his work for publication. In many cases recent discoveries of fossils have forced us to alter the traditional conceptions of the phylogeny of certain groups. I need refer here to two cases only; the superseded conception of the Elasmobranch sharks as primitive, and the final discarding of the idea of the Cyclostomes as secondarily agnathostome. Every modern student of evolutionary and phylogenetic problems should read Abel's *Palaobiologie und Stammesgeschichte* and Sewertzoff's *Morphologische Gesetzmässigkeiten der Evolution*, as these two works embody the morphological, embryological and palaeontological considerations and results of evolutionary and general morphological thought of our day.

Embryologists, with the possible exception of the *Entwicklungsmechaniker* are really comparative anatomists; for whether they are adherents of Haeckel's fundamental law of biogenesis or of von Baer's *Embryonengleichheitsgesetz* they are and remain comparative anatomists, because they are continually comparing embryos with one another or with adults, with a view to ascertaining the phylogenetic position of the group studied. It stands to reason that the embryologist must be convinced that ontogeny does actually in some way or other recapitulate phylogeny, otherwise he is doing mere descriptive work which may be interesting without being important. No classical biological theory has in our time been subjected to greater criticism than Haeckel's *biogenetisches Grundgesetz.* In Russia much has recently been written on the subject by Sewertzoff, and by Jezhikof and Matvejef presumably his pupils. Important new aspects have been stressed in England by Needham, de Beer, Garstang and Macbride. Among the German critics Ehrenberg and Schindewolf are palaeontologists, Nauck an anatomist and Franz a zoologist. In Italy the evolutionist Rosa, in Switzerland the experimentalist Lehmann, in Sweden the embryologist Broman, and in Holland the late Prof. Bolk have all contributed important papers bearing on the subject.

The matter is an extremely important one, for the recapitulation theory is the justification for phylogenetic embryological research among comparative anatomists. Vialleton—and apparently also Canella—discard Haeckel's law in toto, whereas most comparative anatomists would like certain reservations and modifications to be recognized. Some of these are very obvious and very necessary. Neoteny as a phenomenon not only in the individual life of the animal, but as one causing neotenic groups to evolve, must be taken fully into consideration, as otherwise the anatomist or the embryologist would unquestionably go far astray with such groups as Rotifers, Urodeles and tongueless frogs. The phenomenon of neoteny was only studied after Haeckel's time, but the originator of the theory by no means advocated such literal recapitulation of phylogeny by ontogeny as has frequently been imputed to him. Many phylogenetically old organs are no longer recapitulated as embryonic *anlagen,* and degenerate animals have an ontogeny which frequently proceeds towards the adult condition without passing through the hypothetical undegenerated adult stage.

All these reservations and qualifications of the fundamental law of biogenesis are now well-known to embryologists and comparative anatomists, so that it is no longer necessary to warn the experienced worker against a too literal interpretation of Haeckel's hypothesis. Judging by the criticisms levelled at the recapitulation theory the unwary reader might be led to conclude that the phylogenetic interpretation of embryology and comparative anatomy is universally discredited. But this is far from being the case. In connection with this controversy it is interesting to discuss the late Prof. Böker's view of the problem. Böker was one of the most interesting of the younger German anatomists, and his attempts at the rejuvenation of comparative anatomy will be discussed later; at present we are concerned with his views regarding Haeckel's law. On p. 14 of the first volume of his book, which has been hailed as one of the most important anatomical works of this century, he says:

> Ich stehe auf dem Standpunkt des biogenetischen Grundgesetzes F. Müller, C. E. von Baer, E. Haeckel, das besagt, dass in der Ontogenese die in der Phylogenese durchgemachten Umkonstruktionen in den gleichen Reihenfolgen rekapituliert werden, und ich bin der Ansicht, dass es davon eine Ausnahme nicht gibt.

Canella, in his work cited above has the following criticism of Böker's standpoint:

> Il Böker assume, quali fondamenti teorici, criteri direttivi ad un tempo, della sua Morfologia biologica, una serie di principi che dagli uni sono giudicati come ormai scientificamente insostenibili, dagli altri sono stati messi *sub iudice*. (Op. cit., p. 48).

Böker and Canella's views are therefore as the poles apart, and it would be most ungracious of a colleague of theirs to attempt to appraise their respective scientific standings. But I am not nearly prepared to relinquish a hypothesis which has been an inspiration to the classical post-Darwinistic comparative anatomists of the nineteenth and twentieth centuries Time may prove to be on the side of Canella and Vialleton, but we who are in the midst of the fray are possibly not capable of expressing an unbiassed judgment—*es irrt der Mensch, so lang er strebt.*

There are probably very few biologists who would suggest that comparative anatomy should revert to the status of a mere descriptive science—an orgy of luxuriously lithographed anatomical drawings and dubious Latin. Those palmy days have gone for ever for we can no longer conceive of anatomy as anything but comparative. If human anatomists are happy with their gorgeously edited Rauber-Kopsch, Testut or Perrier, their colleagues on the comparative side are quite content to leave them in *otio cum dignitate.* But these colleagues are faced with the problem of putting their own house in order.

The saga of a crisis in the comparative anatomical discipline is to a great extent an organised—not to say manoeuvred-scare calculated to undermine the self-confidence of the morphologist who has no easy task, and has no quick results to show. His field is wide, his science is old and highly organized, and it takes him years to perfect his technique.

It is argued in some quarters that experimental technique has largely supplanted macroscopic and microscopic comparative anatomy. But the experimentalist cannot do without the microscope and microtome, because even he has to interpret his results histologically and histogenetically. This is particularly true of the so-called transplantation school of experimentalists. My first acquaintance with the aims and the methods of transplantationists was in the form of Braus' paper of 1908. Now no one has a greater opinion of Braus' work than I; he was an anatomist of the purest lineage, and his early death after a *Leben der Arbeit* was an irreparable loss to German science. But I felt about Braus' discursion into transplantation what I feel about much of the more recent work along the same lines; the method does not impress me as being sufficiently exact. Anyone working on histogenetical problems knows how difficult—if not impossible—it is to distinguish histogenetic units in the blastematous stage. In the vertebrate limb-bud for instance myogenic and skeletogenous tissue cannot be distinguished until one is enabled to identify the latter in the procartilaginous stage by applying selective stains such as mucicarmine. So uncertain is the histogenesis of the appendicular skeleton, that I cannot consider the derivation of its skeletogenous tissue from the axial mesenchyme as having been proved, although I believe it to take place.

In cases of limb-bud transplantation therefore, the transplantationist is dealing with a histogenetic complex which cannot be ânalyzed histologically before the transplant is grafted. No wonder that the results and conclusions of transplantationists frequently impress one as irrelevant and contradictory.

The severest critics of morphologists are the physiologists; but not those of *pur sang* but the so-called general physiologists. Their criticism may be proclaimed vociferously or in the form of an insidious whispering. It is maintained that morphologists practise a mere descriptive science, that they confine themselves to form and are not interested in function. A more bizarre assertion has assuredly never been made, for if such criticisms were justified, morphology must indeed have descended to the level of photography. In reality the morphologist could not leave function out of consideration even if he were to try; for he must at least be credited with a scientific conscience. Let me quote a case in point: I have recently been interested in the organ of Jacobson of endemic lizards; according to some physiologists, I, as a morphologist, would be content to describe the structure of the organ, such as its bony capsule, sensory epithelium, innervation and blood supply, without troubling myself in the least about the function of these structures. But my aims and methods are in reality entirely different; for in addition to the anatomy I should discuss very fully the filling mechanism of the organ, and should draw upon my knowledge of the comparative anatomy of the organ i.e. upon the conditions obtaining in snakes and mammals. The experimentalists would not be able to study the physiology of the organ as exhaustively as the anatomist; they have tried, but their results have been merely corroborative of those of Prof. Broman who mainly relied upon the methods and deductions of the morphologists.

Canella, whose work has often been cited in the course of this address, is a morphologist who advocates the biological-physiological orientation of comparative anatomy. His views are set forth in the last two chapters of his book, and on the positive side one has no criticism whatever to offer. If I might change a colloquial expression for a moment, I should like to say to Dr. Canella that he is flogging a horse which is very much alive. Comparative anatomy and embryology are already fully physiologically orientated; form is not being described for form's sake but interpreted in terms of function. Palaeontology is not discussed by Canella, but he can rest assured that since the time of Dollo (whom Abel considers to be his true master) fossils are no longer considered as so many dry bones which the ingenuity of palaeontologists is pleased to separate into so many genera and species. Abel, followed by his son-in-law, Prof. Ehrenberg of Vienna, has created an entirely new science from the classical palaeontology of the nineteenth and the beginning of the twentieth century. Abel's credo has been set forth in his book "Paläobiologie und Stammesgeschichte," and Ehrenberg is editing a flourishing journal "Palaeobiologia" devoted to the subject. Palaeobiologists are not mere palaeontologists: they try to deduce from fossils the mode of life of the animals found in a fossilised state. Palaeontology, therefore, is already well on the way to a biological orientation.

The views of two very important morphologists still have to be considered: those of the late Prof. Lubosch of Würzburg and the late Prof. Böker of Jena. The former stood in the direct line of descent from the great German morphologists of the nineteenth century whereas the latter was representative of the younger school of thought. German science has indeed sustained a very great loss through the demise of Prof. Böker who was universally hailed as one of its most promising talents. Böker's ideas were that comparative anatomists had neglected analogies and had concentrated too much on the study of homologies, and that comparative anatomy had become a purely laboratory science. What we should now call field workers were looked down upon as so many well-meaning but unimportant amateurs who were useful only in so far as they were instrumental in procuring material for the laboratory anatomist who would then employ the microtome and microscope in the service of genealogical zoology, which had become the be-all and end-all of the classical comparative anatomist. Such ideas were current in Germany in spite of the existence of that wonderful compendium of ethiology or habits of animals, *Brehms Tierleben* which was being published in one augmented edition after the other, and is constantly being enlarged and brought up to date even in our own time. Böker is apparently an avowed Lamarckist—much to the disgust of his severest critic Canella, who was equally shocked at his adherence to the fundamental law of biogenesis. Böker furthermore believes that ethiology influences morphology i.e. that habits are responsible for structure. I translate from p. 7 of the first volume of his treatise, .

> Environment and relation, i.e. all manifestations of life of an animal are dependent upon the conditions of the environment in which it lives. . . . To every manifestation of life belongs a characteristic anatomical structure, the anatomy of an animal is causally dependent upon biological factors.

Böker states that his *Biological Anatomy* proceeds from the premises quoted above, and adds that his book will shew that these premises are not mere hypotheses, but that they are derived from experience. The entire introduction to volume one (op. cit., pp. 1-17) is of the very greatest importance, and no serious comparative anatomist can afford to neglect reading it carefully, dispassionately and with that open mind devoid of prejudice, which Dante summarised in his frequently quoted admonition: *Apri alla verità che viene il petto* (*Stazio a Dante*).

Since in the opinion of the writer Böker's *magnum opus* is the most thoughtful and inspiring contribution to comparative anatomy of the twentieth century, an occasion will be found to come back to it at a later stage. I shall now briefly discuss the views of the late Prof. Lubosch of Würzburg in connection with the aims and trends of modern comparative anatomy. To Lubosch, as co-editor with Bolk, Göppert and Kallius of the *Handbuch der vergleichenden Anatomie der Wirbeltiere,* was assigned the task of writing an introductory history of the subject, and no one with a wider perspective could have been chosen. He was not only a human anatomist of the very highest calibre, but had a knowledge of comparative anatomy equalled only by the late Prof. Versluijs. Up to his death he was contributing important papers on the century old problem of the evolution of the suspensorium of vertebrates, and particularly on the comparative anatomy of that most difficult of all systems—the musculature. Lubosch's seventy-three pages of introduction on the history of comparative anatomy constitute the most precious legacy that he could bequeath to his younger colleagues. The work was published in 1931, and the only two important discussions along similar lines that have appeared since, are those of Boker in 1935 and of Canella in 1937.

It is tacitly assumed in our days, both in general parlance and in articles in scientific journals, that the terms comparative anatomy and morphology have the same meaning. But Lubosch, who makes out a very plausible case, would like to separate the two completely. He maintains that this separation was introduced by Gegenbaur, as it apparently was. Goethe who coined the term morphology seems to draw no distinction between it and comparative anatomy, but it is not easy to interpret the master's intentions regarding this matter. But Gegenbaur in his work stretching over the period 1859-1901 apparently considered comparative anatomy as an auxiliary discipline to morphology, one which had as purpose *den Bauplan der Formen und ihrer Teile zu enthullen.* This classification was not subsequently adhered to by Gegenbaur, the distinction between the two disciplines disappeared and both were brought into line with Darwinism, or better, were considered as indicative of phylogeny. Canella is quite right when he criticises Lubosch for not warning the reader that Gegenbaur's *vergleichende Anatomie* of his later years was genealogical comparative anatomy.

Paragraph V of Lubosch's introduction cannot but render a disservice to the prestige of comparative anatomy if all comparative anatomists were to react positively to the classification of the morphological sciences therein advocated. The suggestion of Lubosch is to separate comparative anatomy entirely from morphology. The former would then be considered as a science treating of the multiplicity of variation of a particular *Bauplan.* But since we should be forbidden by the strict rules of aetiology to draw any conclusions or make any inferences, the result must necessarily be to stultify any anatomical research whatsoever, and comparative anatomy would become a mere descriptive exercise of the mind. We should certainly refuse to revert to the old typological method which to most of us has a mere historical interest. After reading Lubosch very carefully one is led to the conclusion that as a result of having his knife into Darwinistic comparative anatomy, he was prepared to lead his younger colleagues into what must inevitably prove a blind alley for the science. Comparative anatomical research would then be universally discarded in favour of morphology. Lubosch defines the aims of this latter discipline on p. 70 as follows:

> All those suppositiously aetiological considerations certainly fall within the scope of morphology. The conditions of existence, relations to environment, adaptations and fitnesses (*Zweckmässigkeiten*) on the one hand, the succession of forms during (biological) time as premises for conclusions on the other, belong to morphology and can be classified under two points of view:—the contemplation of the condition (*So-sein*) of the form (*Gestalt*) in (a) space, (b) time.

This definition introduces two untranslatable German philosophical terms. *So-sein* and *Gestalt* with which the philosopher's present will be particularly familiar. The mere morphologist might possibly be none the wiser. I am therefore quoting two further dicta on p. 71 of Lubosch's work,

> Morphology, like mathematics, is not to be considered an inferior science because it does not prove the validity of its tenets by means of causes but by the production of evidence of their being as they are and of their not being able to be different.

Further on, on the same page he states—

> It is not important for morphology to prove individual dependences, but to concentrate on contemplation of complicated conditions as a continuous *So-sein*.

It is not possible to state whether the following formulation and explanation of Lubosch's standpoint is actually that of its author, but it cannot be much different. Comparative anatomy is to describe anatomical conditions and variations only, whereas morphology is to have a wider interpretative scope, in particular as regards the physiological correlation of organs and systems of organs. The attempt to interpret comparative anatomy in terms of phylogeny shall apparently be forbidden. Lubosch's work is more destructive than constructive, and I cannot help agreeing with Canella that the aims and methods of Gegenbaur are not always fairly or correctly interpreted by Lubosch. His essay will always be of absorbing interest to the experienced comparative anatomist, whose command of German should, however, leave nothing to be desired. For Lubosch's style is involved and he presupposes a knowledge of the history of philosophy which very few biologists possess. To a student Lubosch's essay might reasonably prove extremely confusing and I very much fear not to students alone.

It is time to sum up the views of modern workers on the future of comparative anatomy. The criticism of some physiologists that comparative anatomists restrict themselves to form, to the exclusion or neglect of function, is a mere illusion; if these critics were to read accounts of modern research work of their anatomical colleagues, they would realize that such work is as fully orientated physiologically as the nature of the approach will permit. Canella pleads for an ever increasing physiological orientation of comparative anatomy and no colleague will quarrel with his aims and ideals. We should not, however, desire the training of the anatomist to start with physiological speculations which at that stage must be empirical; in fact we should insist that physiologists should have a thorough grounding in anatomy and particularly in comparative anatomy. For no perspective of the form and function of any organ or system of organs can be complete that does not take into consideration the comparative aspect of the matter. Chemical or reflex or responsal physiology will never oust anatomy, as some people delude themselves into believing, since, to choose the very simplest words, no one can understand what an animal *does* before he knows how an animal *is*.

We welcome Boker's new method of approach even if we do not believe that habits are causal to structure. Any attempt at emancipating the morphologist from the laboratory can only earn our appreciation and gratitude, as the biologist is supposed to study life and its manifestations in the first instance. I do not think that any anatomist would seriously advocate what Canella very justly designates as a reversion to the old *Typenlehre* or study of types. Yet that seems to be the logical inference to be drawn from Lubosch's essay. Nor should the biologist be content to devote his energies to morphology as defined by Lubosch, because its boundaries and scope are not sufficiently clearly stated to serve as a guide to the young worker and to those responsible for his training. The experienced morphologist, cognizant of the facts of comparative anatomy, embryology and palaeontology entertains not the slightest doubt regarding the fact of evolution, and will continue to produce evidence in proof of it—that is to say, if he relies upon his commonsense rather than upon any suppositious violation of the aetiological principle. Mistakes will be made, even as Gegenbaur, Gaupp, Wiedersheim and Darwin have made mistakes, but their work has been a never failing inspiration to their less brilliantly endowed but equally conscientious successors in the field of comparative anatomy. Goethe, giant among the pygmies of his time, has a wise criticism and a reassuring consolation for all those who err while striving, when he makes Faust say:

Was glanzt ist fur den Augenblick geboren,
Das Echte bleibt der Nachwelt unverloren.

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THE FORM AND MOTIONS OF THE EARTH

BY

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Presidential Address to Section B, delivered 2 July, 1940.

1. INTRODUCTION.

Perusal of sectional presidential addresses, as printed in the journal of this Association, reveals that the usual course adopted by speakers is to take as subject some aspect of their particular science. In following this time-honoured procedure I have selected for consideration, "The Form and Motions of the Earth," for the following reasons:—

(a) These attributes of our planet are basic concepts and form fundamental principles, not only to the five sciences of this section, but almost equally to the other sciences comprising the spheres of activity of the members of this Association.

(b) To-day, as throughout past history, this topic is full of interest to the savant. it intrigues the philosopher, is fascinating to the dilettante, and exerts an alluring and well-nigh irresistible influence on the cogitations of the man in the street.

(c) There is still an unfortunate paucity of opportunity for inquiring students to receive adequate instruction in these matters, particularly in South Africa: and yet more serious is the lack of any up-to-date, informed, or documented statement, or authenticated summary on this subject available to inquirers. Thus interested seekers after knowledge find themselves involved in a wide and deep search into the literature of the physical sciences.

My subsidiary reasons will be given in the form of quotations.

(d) Bowman (1934: 20) says

> "There are millions of people who still believe the earth to be flat because it is not perceptibly curved as one looks at it casually. It is fantastic, a defiance of common sense and a violation of experience to say that the sun does not move across the sky when it so obviously does. It requires experience, more general observation than can be made on the spot, and the application of technical methods and measurements to *prove* the rotation of the round earth."

(e) Rudyard Kipling in "The Village that voted the Earth was Flat" (1913: 184), makes one of his characters, Ollyett, say: "It *is* an infernally plausible theory. After all, no one has actually proved the earth is round, have they?"

(f) Dr. Woodhouse (1893), a former Professor of Astronomy at Cambridge, is reported to have written:

> "When we consider that the advocates of the earth's stationary and central position can account for and explain the celestial phenomena as accurately to their own thinking as we can ours, in addition to which they have the evidence of their own senses, and scripture, and facts in their favour *which we have not*, it is not without a show of reason that they maintain the superiority of their system—however perfect our *theory* may appear in our own estimation, and however simple and satisfactory the Newtonian hypothesis may seem to account for all the celestial phenomena, yet we are compelled to admit the astounding truth that, if our premises be disputed, and our facts challenged, the whole realm of astronomy does not contain the *proofs of its own accuracy*."

(g) Finally, as recently as 1934, Professor R. C. Tolman, (1934: 14) of the California Institute of Technology, stated:

> "In addition to the Michelson-Morley and Kennedy-Thorndike experiments there have been a considerable number of other types of experiment devised to detect the motion of the earth through the ether, all of which have led to negative results."

It would appear then that our subject, which has engaged the attention of thinking men of all ages from the remotest antiquity, is still of very considerable world-wide interest.

2. ABSTRACT SPECULATIONS AND REASONINGS OF ANCIENT PHILOSOPHERS.

By their unaided vision and observation in and around their immediate environments, mostly in river basins whether in Babylon, Egypt, Greece, India or China, all the ancient wise men seem to have arrived at the conclusion that, in spite of the many noted irregularities in a vertical sense—in some cases amounting to several thousand feet—the general shape of the terrestrial surface was basically flat. (Skeat 1923: 15-19 and Wright 1925: 53). To the Babylonians the earth formed the floor of a domed casket, with its centre in the snow-clad mountains near the source of the river Euphrates. Early Egyptians imagined themselves to be in a shallow basin, forming the centre of an oblong earth. A Brahmin represented the earth as a flattened dome, or bun-shaped solid, supported by four elephants standing on the back of a giant tortoise. Scandinavian mythology adheres to the concept of a disc-shaped earth, surrounded by an ocean, with an ice-bound mountainous outer rim, reputed to be the abode of giants.

According to Tozer (1897: 20-21) Homer (circa 800 B.C.) probably crystallised the views of the ancient Greeks in the Odyssey—that book of metrical sailing rules, that descants so picturesquely on the long summer days and long winter nights of the fjord-coasts of a land in the far north. Homer's description of the earth was of a circular plane, surrounded by the Ocean, a broad and deep river, which returned upon itself and was the parent of all waters. Nevertheless, after a careful examination of all the available evidence, J. K. Wright (1925: 15) librarian to the American Geographical Society, states: " nearly all scholars of antiquity after the fifth century before Christ thought that the earth was a globe "; and further quotes the Jesuit father F. S. Betten (1923: 86) as stating: " We have . . . at least one witness in every century to the tradition of the sphericity of the earth."

The earliest mention of the possibility of the earth being round comes from the Pythagorean school of philosophy, (6th cent. B.C.), the members of which sect " saw not a world of matter, nor a world of energy, but one of form " (Taylor 1940: 24). Basing his arguments on abstract reasoning and on perfection of form and of number, Philolaus (c. 480 B.C.) taught that the earth was a sphere which, with the seven other known wandering bodies—the sun, moon, mercury, venus, mars, jupiter and saturn—plus an invented ninth body which he called Antichthon or counter-earth, all revolved around a tenth imaginary "unseen central fire," whose light was supposed to be reflected by the sun as well as by the planetary bodies (Heiberg 1922: 12-13).

Plato (427-347 B.C.), the creator of the analytical method, could not, however, accept the reality of the visible, irregular movements of the planets in the sky. Holding firmly to the central position of the earth, he propounded to the Academy the problem of determining by what combinations of circular motions the apparent movements of the planets could be explained. This task appears to have been satisfactorily performed by Eudoxus of Cnidos (c. 365 B.C.) the probable founder of spherical geometry, by the use of numbers of homocentric spheres (Heiberg 1922: 35-36). According to Aristotle, Eudoxus is the first to have estimated the circumference of the earth, giving as the distance 400,000 stades, or approximately 44,000 miles, assuming the stade to be 177·6 metres. But Heraclides Ponticus (388-315 B.C.)

solved the Platonic problem more simply by formulating the so-called Tychonic planetary system, in which mercury and venus are made to move around the sun, while the sun and the other planets revolve around the earth. He also taught the rotation of the earth on its axis, though still regarding it as the centre of the universe (Tozer 1897: 166).

In addition to his remarkable powers of observation and scientific deduction, to be noticed presently, Aristotle (384-322 B.C.), the founder of scientific geography and deservedly yclept "the philosopher," stated that physical laws require the earth to be spherical owing to the tendency for all matter to fall together towards a common centre. But he supposed the earth to be stationary in the midst of the universe.

After subscribing to the geocentric view of the universe in his early days, Aristarchus of Samos (310-230 B.C.) having developed Heraclides' theory of the rotation of the earth, in his later years anticipated the Copernican theory (Taylor 1940: 47). He considered the sun remained unmoved in space and the stars fixed in the heavens. Around the sun the spherical earth and the other planets moved along circular orbits. In this manner he explained the phenomena of sunrise and sunset. Aristarchus' theory was rejected by later Greek and mediaeval astronomers (Glover **1936**: 234), particularly by Posidonius, its only supporter being the gifted, original researcher and astronomer Seleucus of Seleucia (c. 150 B.C.). But the greatest mathematical genius of antiquity, Archimedes of Syracuse (287-212 B.C.), regarded the sphericity of the earth sufficiently proved, and deduced therefrom that the sea-surface must be convex.

Strabo of Amasia in Pontus (63 B.C.-21 A.D.), whose "Geography" provides the most complete and accurate summary of the knowledge of the earth then existing, was the first to use the gradual revelation of objects when approaching the shore over the sea as an argument in favour of the globular form of the earth (Tozer 1897: 168). Pliny the Elder, of Verona (23-79 A.D.) made the rotundity of the earth popular in his day by his statement "The earth is round because, when approaching the shore, the coast is seen first from the top-mast of the ship."

The last of the ancients to meditate upon the problem and to contrive a system to explain celestial and terrestrial phenomena was Claudius Ptolemaeus of Alexandria, whose speculations were made public between 127 and 151 A.D. Whilst retaining as an essential feature of his scheme

Aristotle's theory of a central, fixed and immovable, globular earth, Ptolemy invented a complicated and cumbrous system of seventy-five crystalline globes, using only perfect movements in their working (Ball 1906: 23). He arranged these globes one within another so that they illustrated the motions of the sun, moon and the other planets around the earth in wavy loops called epicycles, and so endeavoured to satisfy the observations made by Hipparchus (190-120 B.C.). When, still later, further vagaries were noticed in the movements of the celestial bodies, Ptolemy introduced another independent motion for each planet using for this purpose a second epicycle.

3. BIBLICAL EVIDENCE AND RELIGIOUS TEACHINGS.

Whilst the doctrine of a spherical earth came to be generally accepted amongst the intellectual people towards the dawn of the Christian era and was preserved with other ancient knowledge by the Arabs, the idea of a flat earth survived as a popular conception amongst the plebeians and curiously also amongst the religious orders. Thus Lactantius Firmianus (260-340 A.D.) "denied the conception of a spherical earth and its implications (such as the antipodes), not only as being against the teaching of the Bible but because he personally thought them impossible" (Dickenson & Howarth 1933: 43). Cosmas Indicopleustes of Alexandria (c. 548 A D.), representing the christian cosmographers of the dark ages who endeavoured to reconcile geographical theory with the literal sense of Holy Scripture, showed the earth as a rectangular strong-box with a semi-cylindrical lid, having Jerusalem in a central position on the floor, and four great gulfs breaking in from a circumambient ocean. His representation appears to have been designed to meet the requirements of the following texts: Isaiah XI, 12; Isaiah XL, 22; and Ezekiel V, 5. Concerning the appended list of Biblical texts (1), which are relevant to our subject, my colleague, Dr. A. van Selms has checked them with the manuscripts, and has consulted the foremost authorities. He assures me that no serious discrepancies have arisen from or in the process of translation, but his comments on the texts are very illuminating and well worthy of publication. In passing we may note that "the ends of the earth," so often mentioned in the Bible were sought frequently and thoroughly by many travellers in the middle ages with the fond hope that they might succeed in touching the heavens. But these travellers found that, however long their journeyings, the ends of the earth, like the heavens, were just as far off as when they set out on their quests (Gregory 1894: 20).

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(1) Joshua X, 12-14; 1 Samuel II, 8; Job IX, 6-9; XXVI, 7; XXXVII, 3; XXXVIII, 6 and 13; Psalms XIX, 6; XXIV, 2; LXXIV, 16-17; XCIII, 1; XCVI, 10; CII, 25; CIV, 5; CXIX, 90; CXXV, 1; CXXXVI, 6; Proverbs III, 19; VIII, 29; Ecclesiastes I, 4-5; Isaiah XI, 12; XL, 22; XLII, 5; XLIV, 24; XLV, 12; XLVIII, 13; Jeremiah XXXI, 35-37; Ezekiel V, 5; VII, 2; XXXVIII, 12; Zechariah XII, 1; I Corinthians XV, 40-41; II Peter III, 5; Revelation VI, 13; VII, 1; VIII, 10.

Even down to the present day geoplanarians often quote the scriptures in support of their assertions. But whilst the applicability of some of the texts used for this purpose may be questioned, so far I have not been able to find one zetetic planeist making any mention of the pertinent statement in Job XXVI, 7. "He stretcheth out the north over empty space, and hangeth the earth upon nothing." Again, whilst maintaining that the Bible is literally true, modern geoplanarians have displaced Jerusalem from its traditional position at the centre of the circular disc of the earth, making instead the north terrestrial pole the hub of the universe (Pratt 1921: 8-9; and Venter 1939: 12).

4. EARLY DOCUMENTARY EVIDENCE.

The first map of any part of the earth, of which we have any record, Figure 1, (1) is preserved in the British Museum, and has been variously assigned to Babylonia about the eighth century B.C. (Skeat 1923: 15), and later with more probability to the Sumerians about 2,700 B.C. (Dickenson & Howarth 1933: 5). On a brown clay tablet it shows a river encircling Babylonia, Assyria and the adjacent regions. But beyond this circle project four triangles, each representing a district, one being labelled "3 (?) days' march; Place where the sun is not seen." We can conclude, then that the river circle is meant to form the boundary, not of the whole earth, but of a portion of it only.

Other ancient maps, as, for example, those of Homer (800 B.C.) the poet, of Hecataeus of Miletus (520 B.C.) the father of Geography (Tozer 1897: 71), of Herodotus of Hallicarnassus (484-425 B.C.) the historian and traveller

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(1) I am indebted to Mr. G. S. Coetzee for assistance with the diagrams.

(Butler 1912: XXV), and of Strabo of Amasia in Pontus (63 B.C.-21 A.D.) Greek historian and geographer (Tozer 1897: VI: 239), are all oval in form, with some part of the eastern Mediterranean Sea in the middle. But, even the oldest which place Greece at the centre of the disc or oval, do not actively support the ancient Greek idea that the "omphalos" stone marked the centre of the earth, for Delphi, the site of the oracle and of the stone, is not marked on any of the maps. Hildegard of Bingen (1,098-1,179 A.D.), too, seems to have based her peculiar egg-shaped earth idea upon the oval form of the maps (Wright 1925: 90, 152 and 424), whilst the fact that the map of the world by Eratosthenes of Cyrene (276-194 B.C.), the keeper of the Alexandrine library, who founded scientific Geography, and measured the circumference of the spherical earth, is also oval entirely precludes the inference being drawn that these flat representations of the earth are in any way to be regarded *per se* as concrete evidence of their authors and designers being geoplanarians.

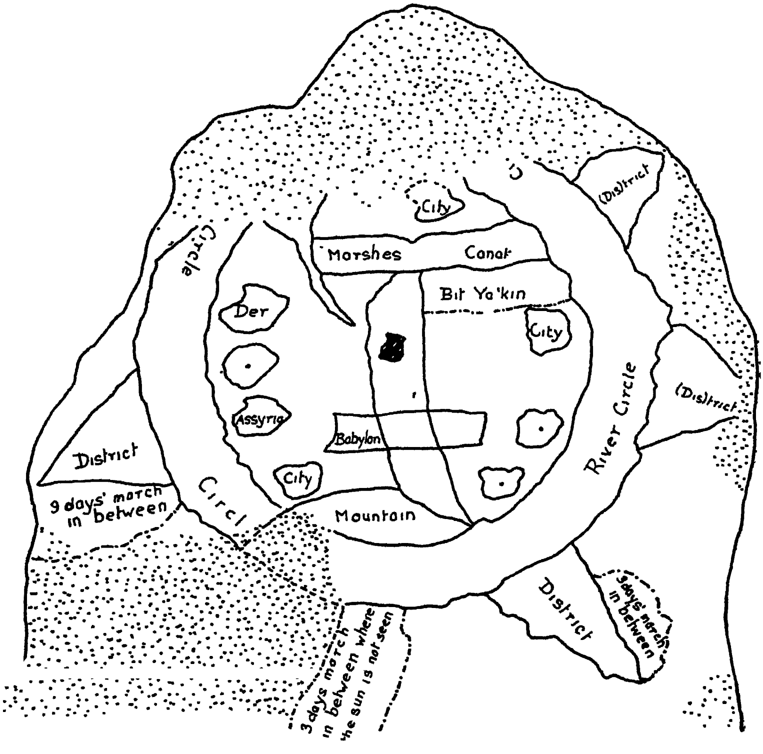


Figure 1. (a). (Plummer).

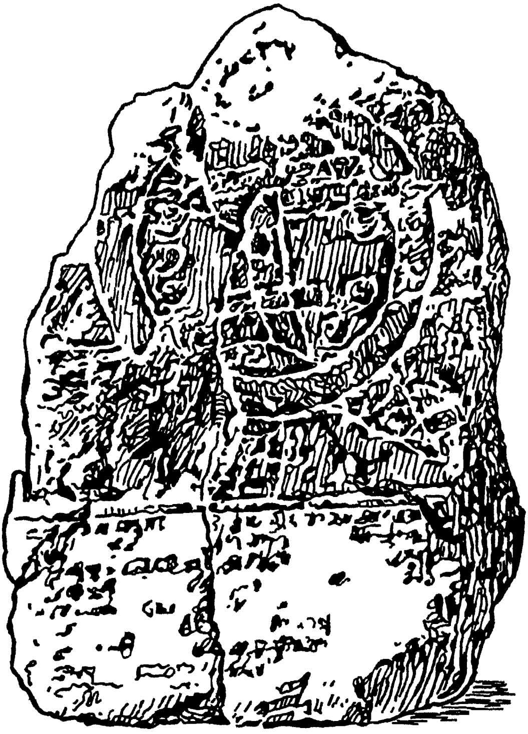


Figure 1. (b). (Plummer)

Ptolemy's map of the then known world, consisting of Europe, most of Asia, North Africa and the Indian Ocean (150 A.D.), closely approximates to a modern map of those areas, drawn on Bonne's projection, and clearly indicates on the part of the designer full recognition of the necesstiy for making due allowance for the spherical character of the earth and for the inclination of the meridians to one another (Tozer 1897: 343).

5. Early Observations.

(a) The great Aristotle is credited with first drawing attention to the circular shadow cast by the earth on the moon's surface during a lunar eclipse. He also mentioned the apparent changes in the positions of the stars as seen by a traveller when journeying from north to south, the disappearance of some stars below the northern horizon and the appearance of others above the southern horizon. Although the Chaldeans named the twelvefold division of the zodiac according to the twelve full moons which occurred in successive parts of it (Clerke 1926: XXVIII: 993), none of the ancients seem to have drawn any inference from the facts that along any particular parallel of latitude, on any given night of the year, weather permitting, if observations are made at precisely the same local mean times, the same stars are to be seen at the same altitudes and in the same parts of the sky relative to the observer, whatever his longitude, and also that all visible stars culminate about four minutes earlier each succeeding night throughout the year in all latitudes. The following is a list of bright stars that are close to the meridian at about eight p.m. local mean time, in latitudes corresponding to South Africa throughout the Southern Hemisphere, for each month of the year.

Table I.

Stars Close to the Meridian at 8 p.m., L.M.T.

January.

Algol. β Persei.
Alcyone. η Tauri.

February.

Aldebaran. α Tauri.
Rigel. β Orionis.
Capella. α Aurigae.
Bellatrix. γ Orionis.
Nath. β Tauri.
Betelgeuse. α Orionis.
Mirzam. β Canis Majoris.
Canopus. α Argus.

March.

Athena. γ Geminorum.
Sirius. α Canis Majoris.
Castor. α Geminorum.
Procyon. α Canis Minoris.
Pollux. β Geminorum.

April.

Alphard. α Hydrae.
Regulus. α Leonis.

May.

Denebola. β Leonis.

June.

Spica. α Virginis.
Arcturus. α Bootis.

July.

Alphacca. α Coronae Borealis.
Antares. α Scorpii.

August.

Vega. α Lyrae.

September.

Altair. α Aquilae.
Deneb. α Cygni.

November.

Formalhaut. α Piscis Australis
Markab. α Pegasi.

December.

Alpheratz. α Andromedae.
Hamal. α Arietis.
Achernar. α Eridani.

N.B. No bright stars are close to the meridian at 8 p.m. in mid-October.

(b) Aristarchus (310-230 B.C.) drew attention to the phenomena of sunrise and sunset, which he stated were explained by the form and motions of a telluric sphere. Certainly, the rotation and revolution of a globular earth affords the simplest and only complete explanation of the following series of complex phenomena:—

(i) the rising, culminating and setting of the sun, moon and stars variously at different times, at distinct and separate places, on the same parallel of latitude;

(ii) the culmination of each celestial body, whatever its altitude above the north or south horizon, at precisely the same moment of time throughout any meridian of longitude, for any observer to whom the celestial body is visible;

(iii) the rising and setting of the sun at exactly similar local mean times at all places on the earth's surface, excepting those closely adjacent to the terrestrial poles, at the times of the vernal and autumnal equinoxes (Plummer 1939: 13-17);

(iv) the rising of the sun at earlier local mean times and its setting at later local mean times during the summer at places of higher latitude in each of the northern and southern hemispheres;

(v) the continued appearance of the sun above the horizon for more than twenty-four consecutive hours for all observers within the Arctic and the Antarctic Circles at the times of their respective summer solstices.

(c) Eratosthenes of Cyrene (276-194 B.C.), the learned keeper of the Alexandrine library, by observations of the sun taken at noon on a midsummer's day from Alexandria—having previously made certain that the sun was then practically vertical at Syene (Aswan), and believing both places to be on the same meridian—computed the earth's circumference to be 250,000 stades, or 25,000 miles, a very creditable approximation to modern estimates, which are about one half per cent. less (Tozer 1897: 171-2). He also calculated the extent of the inhabited surface of the earth, and stated it to be 78,000 stades from west to east, and 38,000 stades from north to south.

(d) Hipparchus of Nicea in Bithynia (190-120 B.C.), the most accurate astronomer of antiquity, by careful observation of the celestial bodies, determined the length of the sidereal year, the obliquity of the ecliptic and of the moon's path, and the eccentricity of the sun's (apparent) orbit with considerable accuracy (Clerke 1926: II: 810 and Buckley 1927: 18). The results of his observations rendered the earlier theories quite inadequate and obsolete, and, as has already been noted, directly led to the formulation of the Ptolemaic conception of the universe.

(e) Posidonius the Stoic (130-50 B.C.), spoken of as the most intelligent traveller and the last independent researcher in antiquity, achieved an unassailable position, but his influence on the then current and later geography was not entirely fortunate. Through taking observations to the star Canopus (α Argus) from both Alexandria and Rhodes,—owing to inaccuracies in the observations and in the computation of distance over the Mediterranean Sea between these places—he originated a serious error in his calculation of the circumference of the earth. His result of 180,000 stades, was 18% less than the modern value, whilst Eratosthenes' estimate was only one half per cent. in excess (Heiberg 1922: 79-80). Posidonius also rejected the heliocentric system of Aristarchus, but his high scientific reputation caused Ptolemy and others to accept his dicta without question (Tozer 1897: 192), and his data were quoted selectively, as well as those of Eratosthenes, by Columbus.

6. INFLUENCE OF THE RENAISSANCE.

Following on the crusades, and also arising from the religious and commercial journeyings into the interior of Asia and of northern Africa, the wider knowledge that accrued of distant places, new customs, religions and ideals; the contacts that were made with different modes of life and systems of government; and the information gained of other methods of spending leisure time; all resulted in the people of Europe becoming more cosmopolitan, and further aroused in them a revival of interest in the actions, thoughts and writings of the ancients. Thus Columbus (1447-1506) was able to quote Ptolemy as his authority for the rotundity and size of the earth, and Eratosthenes as having computed the area of surface inhabited, as well as having stated that it was possible to get to the east by sailing west if the ocean were not so vast (Glover 1936: 260). It is of passing interest to note that Columbus was the first to suggest that the figure of the earth was an ellipsoid with three unequal axes. In a letter, written in October 1498, to King Ferdinand and Queen Isabella, Columbus expressed the opinion, " I have come to the conclusion respecting the earth, that it is not round as they describe but of the form of a pear" (Major: 1870: 134).

A man strongly influenced by such advanced thinkers as Regiomontanus (1436-1476) and Domenico Maria Novara (1454-1504) was Nicolaus Copernicus (1473-1543), the Polish astronomer, who had just reached manhood when Columbus discovered America. Having noticed, and cogitated upon, the variations in brightness, magnitude and position of the planet mars in the sky, he became much impressed by the simplification introduced into the older planetary theories by referring the motions of these wanderers to the sun as centre of the universe. Basing his reasoning on the principle of the relativity of motion in circular planes, he revived Aristarchus' theories (Hart 1924: 72) in his book De Revolutionibus Orbium Coelestium, published in 1543, and thereby laid the foundation of modern conceptions.

In September, 1519, Ferdinand Magellan set out on his great voyage of circumnavigation of the globe. At its conclusion, in September 1522, the survivors under Sebastian del Cano, made a pilgrimage in shirts and bare feet, with tapers in their hands, as humble penitents to the shrines of St. Maria of Victory and of St. Maria de Antigua in San Lucar, as they had discovered at the Cape Verde Islands that they had been keeping the fasts and festivals on the wrong days. Through following a continuously westerly course they had experienced one less sunrise and one less sunset than their friends who had remained behind (Pigafetta 1916: 83-4).

Johann Kepler of Weil (1571-1630), after visiting Tycho Brahe (1546-1601) in January 1600 and admiring his accurate observations, was constrained to abandon his own earlier theories, which had been founded on abstract speculations. After preparing the Rudolphine tables, so indispensable to seventeenth century navigators, and making a continuous and detailed study of the motions of mars in the light of the Copernican theory, by diligent application he discovered a discrepancy of about eight minutes of arc between theory and observation concerning this planet (Jeans 1926: XXXI: 324). His endeavours to eliminate this discrepancy led to the formulation of his three fundamental laws which explain the motions of all the planets.

The increasing theoretical evidence of a spinning spherical earth, in translatory motion around an unmoving sun, was enormously reinforced by the discoveries of Galileo Galilei (1564-1642). He showed remarkable courage, even great daring, in confounding his contemporaries in 1590 with the famous experiment of falling bodies from the leaning tower of Pisa, his object being to test, and to prove wrong, the writings of the revered philosopher, Aristotle (Hart 1924: 103-124). In 1609, with the aid of his telescope, he was the first human being to see and appreciate the significance of four important celestial pheuomena:—

(a) The irregularities in brilliance, and therefore in surface, of the mountains, valleys, craters and plains (mare) exhibited on the moon by the changing incidence of the light of the sun. The foreshortening due to the curvature of surface in the lighted limb, the sinuosity of the terminator, or division between the lit and unlit parts, the "outliers" of sunlit peaks in the darkened portion and the shadows thrown by the laterally illuminated mountains would have been very apparent even in his weak telescope, and would thus have shown the moon to be a globular body.

(b) The enlargement of the wandering planets into discs like the moon, while the fixed stars remained points of light no larger than when seen with the naked eye, except for the iridescence due to chromatic dispersion in his simple telescope.

(c) The revolution of four satellites around a greatly enlarged Jupiter, the innermost satellite visible, Io, moving so quickly that it takes less than two terrestrial days to complete one circuit (Moulton 1927: 174).

(d) The appearance of sunspots, that moved so regularly over the sun's surface that their changes in position, size and shape—particularly when near the edge of the disc—could only be explained by the rotation of that much magnified body (Abetti 1938: 20).

Now each of these phenomena was visible to anyone who looked through the telescope, but the first, third and fourth mentioned were in direct opposition to the teachings of Aristotle. So, they were dismissed by the learned churchmen of the time as "a deception of your senses, or of your glasses," and Galileo's colleague, the principal Professor of Philosophy at Padua, "pertinaceously refused" to gaze through the instrument.

The Theory of vortices (Wallace 1936: VIII: 86) of René Descartes (1596-1650) being a theory with explanations, in contrast with Kepler's facts without explanation, caused a great stir amongst the philosophers of his day and was generally accepted. But it reverted to the Copernican circular orbits, held the stage for only a brief interval of time and need not occupy our attention further.

But Sir Isaac Newton (1642-1727) sifted, co-ordinated and consolidated the views on cosmology, held previous to his day and generation, into one logical and coherent system. which satisfied the astronomical observations made up to the present century, with one important exception, the discrepancy of forty-two seconds of arc, between observation and calculation in respect of the advance of the perihelion of mercury (Buckley 1927: 32-43 and 226). But further confirmatory evidence of the translatory motion of the earth round the sun was forthcoming when Olaus Römer (1644-1710), a Danish astronomer, in 1676 noted that light from jupiter's satellites took about eleven minutes to cross the earth's orbit, and by this means he was able to obtain a first approximation of the velocity of light through space.

The evidence provided by the experiments of James Bradley (1693-1762) is even more striking. By observations of α Draconis in 1725 he was investigating the annual parallactic shift of that star, an apparent movement depending only upon the distance of the star from the observer. He noticed repeatedly that the position of the star was displaced by a small, but measurable, amount in a quite unexpected manner. By keeping fifty stars under almost continuous observation, he found them all to be affected in precisely the same manner, the angle of displacement being 20·47 seconds of arc (Grimsehl 1935: V: 425-6) for each star, irrespective of its position in the sky, or its distance from the earth. This purely optical phenomenon, which was found to be not at all dependent upon Newton's laws Bradley called the aberration of light. He later gave a completely satisfactory explanation of its effects as resulting from the combination of the velocity of the earth in its orbit with that of light. For stars situated in the ecliptic the motion is in a straight line, for stars at the poles of the ecliptic the motion is circular and for intermediate stars it is elliptical, the apparent displacement of each star being always in the direction of the earth's orbital motion. The angle subtended at the earth's surface by half the straight line, by the radius of the circle and by the semi axis major of the ellipse amounts in all cases to 20·47 seconds of arc. When, however, being assured of the correctness of his interpretation, Bradley made the necessary corrections to his observations, he found that he was still left with a small residuum, which had no annual cycle and so could be neither an aberrational nor a parallactic effect. Later, he accounted for most of this residuum as resulting from a nutation of the earth's axis, which he again showed was due to the influence exerted by the sun and moon on the earth during the earth's annual revolution. The rest of the residuum remained unaccounted for until 1890, when S. C. Chandler showed it to be the result of a slight variation in terrestrial latitude, which arose from the rotation of the earth and its slight but definite departure from a perfect sphere (Turner 1904: 177-220).

The regular annual shift of the lines in the spectra of stars is another phenomenon which demonstrates the revolution of the earth around the sun (Russel, Dugan & Stewart 1926: I: 135 & II: 650; Larmor 1900: 14; Spencer Jones 1923: 299).

7. MODERN SPECULATIONS.

The modern religious movement, known as fundamentalism, takes very little interest in our subject, and then only incidentally, in so far as it is affected by the fourth of the five "points of essential doctrine,"—the inerrancy of Scripture (Brown 1926: XXX: 130), an aspect which has already received consideration.

Although the essentially circular character of the limits of the horizon in all directions, from all places where mountains do not intervene, has been recognised everywhere throughout history, recently it has been used as an argument for considering the earth flat, but round or oval in outline. One geoplanarian of the present day, however, Mr. E. L. Venter, restricts curvature on the earth's surface to the east and west directions in a manner that is not at all clear (Venter 1939: 5). But disagreement between advocates of the flat and of the globular earth theories always arises over the rate of increase in the radius of the horizon with the greater altitude attained by the observer; a demonstrable fact, which can be personally experienced, but nevertheless lends itself neither readily nor fully to reasoned argument. This is because it is not just a matter of viewing objects at a distance in perspective over a flat or a convex or a concave surface (c.f. Rectangle 1899: 7 & 56), but the problem is very considerably complicated by the difficult, intractable and irregularly variable phenomenon of refraction. On this subject, Close and Winterbotham state (1925: 126):

> The effect of refraction (on observations) varies so much with the place, season, and the time of day, that it cannot be calculated, nor can allowance be made for it . . . The laws governing refraction are extremely complicated, but are such that its effect is greatest near the ground, and increases rapidly as the length of sight increases.

Steady ascent of the slopes of Elsies Peak, south-west of Fish Hoek, Cape Province, will reveal to the observer gazing eastwards on a clear day, first Seal Island standing out a little clearer than the background, and then the islet gradually separating itself from the hazy, ill-defined eastern land bordering the coastline of False Bay in the distance. Later, on rising still higher, a narrow strip of water will come into view beyond the islet. Continued ascent will cause this strip of water gradually to widen, and the beach, and architectural and other details of the Strand can be made out on a clear day, particularly with the aid of field-glasses. These details were not visible, even with field-glasses, from the Fish Hoek shore, being hidden behind the bulge of the waters of False Bay, which rise about 100 feet above the chord joining Fish Hoek and the Strand. In the course of such an experiment the dip of the horizon and the curved nature of the sea-water surface are particularly clearly brought home to the observer.

The statement is occasionally made in newspapers that Danger Point lighthouse is visible from Smith's farm on the Cape Peninsula, over fifty miles away (Cape Times 1894). Putting aside any suggestion of possible confusion of the lighthouse beacon-light—which flashes in groups of three every 40 seconds—with a riding light swinging on a nearby ship, the phenomenon is a very remarkable one. With a spherical earth under average conditions of refraction, for an observer on Smith's farm, at a height of 250 feet above mean sea level (Cape Times 1894 and map of Cape Peninsula 1933), to see the beacon light on Danger Point—distant 53 statute miles—flashing, and not its reflection in suitably placed low-lying clouds, the light would need to be nearly 600 feet above mean sea level instead of 150 feet as stated on the nautical chart (no. 2082), and in the Africa Pilot (1929: III: 72). Thus the effect of the abnormal refraction is apparently to raise the beacon light to almost four times its actual height above mean sea level. It may further be mentioned that a drop of 4 feet in the level of the sea surface at the time of observation would be equivalent to an increase in the height of the beacon light on Danger Point of 20 feet (Admiralty Manual 1928: 206).

It is important to notice how infrequently and at what times of day and season the spectacle is mentioned as being visible. Usually the appearance is reported at rare intervals, and then (a) in winter, when the atmospheric pressure is high

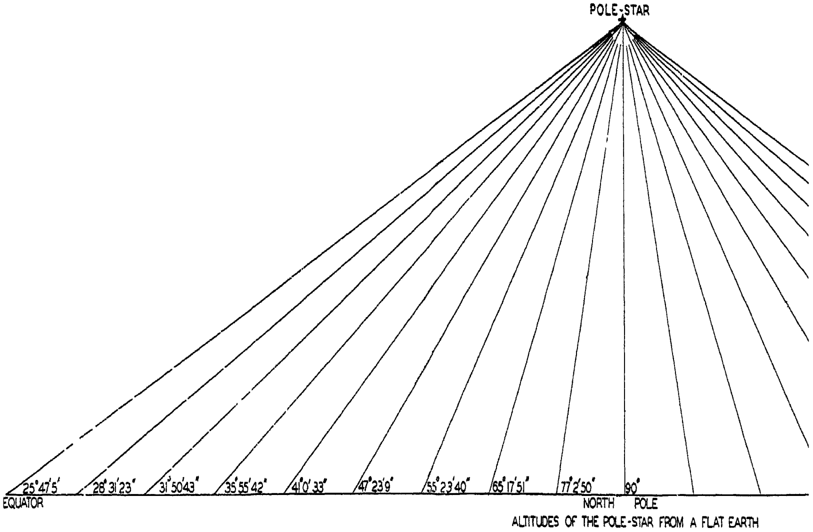


Figure 2. a (i) (Scale 1/63,000,000

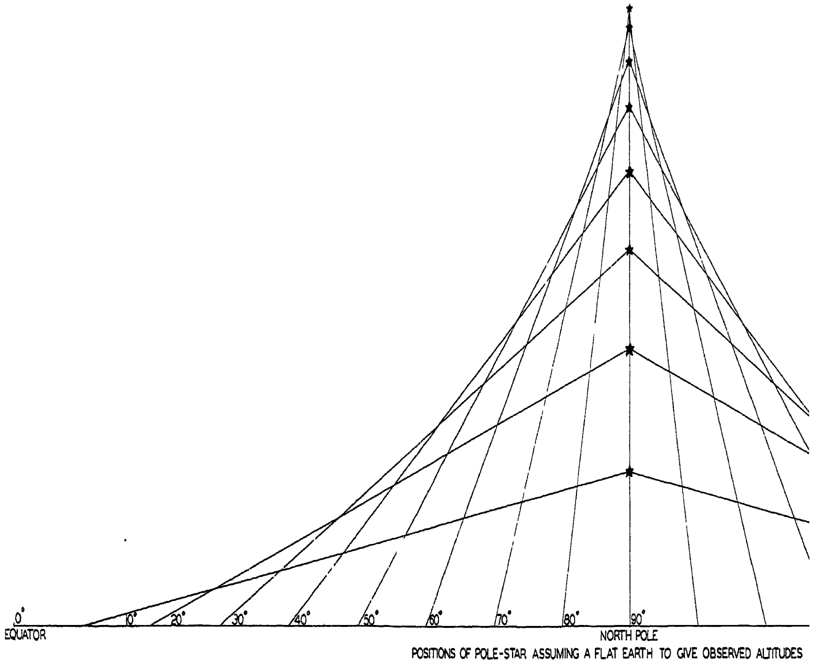
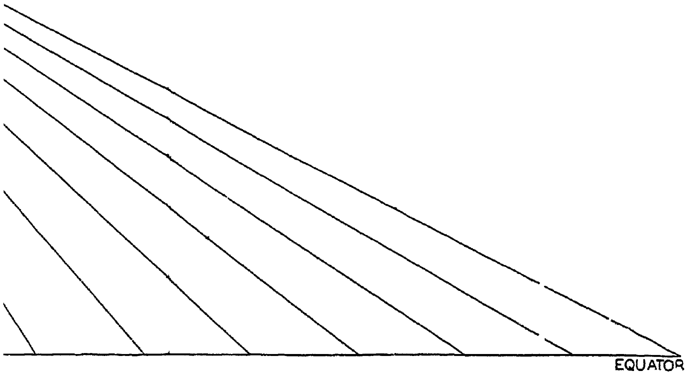

0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
EQUATOR
NORTH POLE
POSITIONS OF POLE-STAR ASSUMING A FLAT EARTH TO GIVE OBSERVED ALTITUDES

Figure 2. a. (ii). Scale 1/63,000,000.)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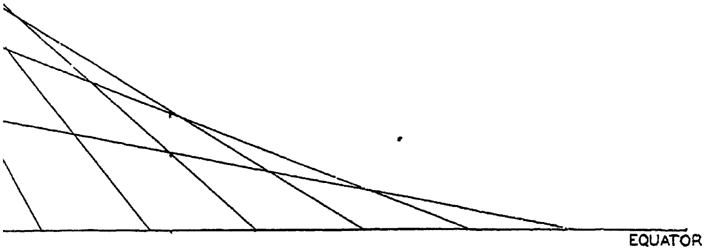
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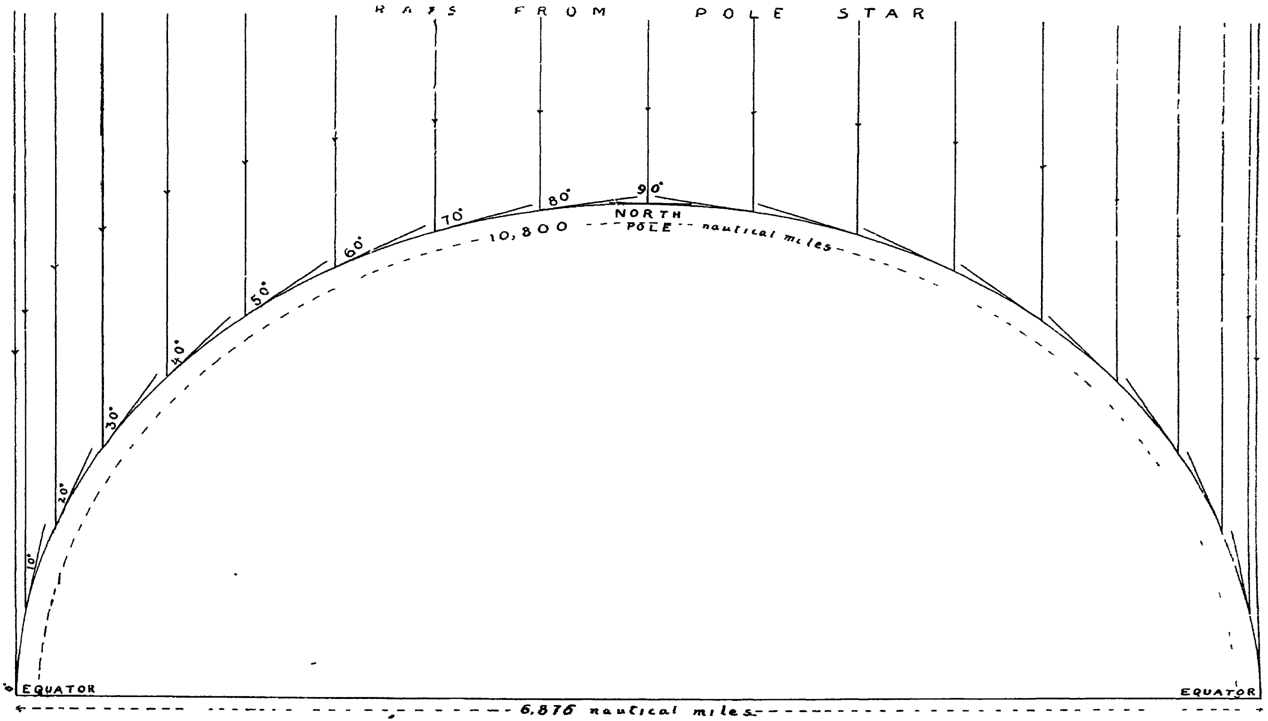

Figure 2. b. (Scale 1/63,000,000.)

Reeves 1935: 193) and when berg-winds are prevalent (Climate and Meteorology 1939: 41), causing the downward drift of warm masses of air from the interior over the sea surface near the coast, and (b) at night, some three or four hours after sundown, when free radiation has caused a very considerable difference in temperature between the air in contact with the rapidly cooling land surface and that just above the much warmer Agulhas current. The depths of the water, too, off Danger Point are very irregular (Africa Pilot 1929: III: 71). Under these conditions, refraction will, of necessity, be very abnormal, the refractive indices of the different layers and belts of the atmosphere varying greatly in quite short vertical distances, and certainly very considerably over large horizontal distances, particularly when in a direction roughly parallel with a much indented and fairly steep coastline. In winter the whole south coast of the Union of South Africa frequently experiences mirages both inferior and superior as well as fata morgana in daylight (Sunday Times 1939: April 9th). At night-time, the remarkable appearances are likely to be both more frequent and much more intense. Unfortunately, since the light only, and not the lighthouse, is seen, the observer is not easily convinced that he is witnessing a mirage effect, possibly involving inversion of the object viewed. (See Admiralty Weather Manual 1938: 294). However the phenomenon is sufficiently striking, and the subject of abnormal visibility of great practical importance to sea- and air-navigation, while the vagaries of refraction—both vertical and lateral—have been so very little studied in this country, that it is highly desirable that organised and critical investigations into these matters should be instituted as soon as possible.

The Bedford level experiment of A. R. Wallace (Skeat 1923: 27). carried out in 1870, provides a practical demonstration of the curvature of a still water surface, the amount of departure of the canal surface from the chord at its centre tween the two stations—or versed sine—being found to ount to six feet in a distance of three miles.

Another difference in interpretation arises from the appearance of the star Polaris, α Ursae Minoris, as seen from different latitudes in the northern hemisphere. For purposes of comparison figure 2 has been drawn to depict the altitude of the pole star as observed from places situated at intervals of 10° of latitude from the Equator to the North Pole:—

(a) on the assumption of a flat earth, the data being taken from Venter (1939: 3 & 13);

(i) reckoning Polaris to be fixed at 3,000 miles above the North Pole.

(ii) showing a number of positions for Polaris, differing from zero above the earth, as seen from the Equator, to 3,913 miles as seen from 80° North Latitude (Hoddinott p. 12).

(b) on the assumption of a spherical earth with Polaris an infinite distance away (¹). The diagrams are drawn to the same scale: 1/63,000,000. The base lines in figure 2a (i) and (ii), and the semicircle in figure 2b, each representing 10,800 nautical miles, and the effects of refraction are ignored in them all.

8. MODERN MEASUREMENTS OF THE GEOID.

From the beginning of the sixteenth century more and more elaborate attempts have been made to determine, by surveying methods, the correct size and incidentally the exact form of the earth. The first series of measurements were associated with the names of Jean Fernel (1497-1558), Willebrord Snell (1591-1626), and of Richard Norwood whose measurement of a degree of latitude as 367,176 feet between London and York (1633-7) was a very fair estimate (Clarke & Helmert 1926: VIII: 802). Then Jean Richer's experience with his clock, which lost two-and-a-half minutes daily at Cayenne (about 1672), after having kept perfect time at Paris, supported Newton's mathematical speculations that the earth's form bulged at the equator (Hinks 1933: 217). After J. and D. Cassini had shown (1684-1718) that meridional measurements across France exhibited the earth's form as a prolate spheroid, the action of the Academy of Sciences at Paris, in sending expeditions to Peru in 1735, and to Tornea in Finland in 1736, initiated geodetic measurements that have grown in magnitude, scope and importance to the present day.

Now the shape and size of the earth are determined by the accurate measurement of carefully selected base lines, supplemented by astronomical observations for latitude,

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(¹) Polaris is reckoned to be 40 light years or 235,000,000,000,000 miles from the earth by astronomers (Moulton 1927: 92).

longitude, and azimuth of rays, and by trigonometrical observations. The results are compared for agreement as to shape, to the varying changes in pendulum oscillations observed at different places on the earth's surface (Hinks 1933: 219), and beneath the sea (Vening Meinesz 1928: 144), and in regard to both shape and size to the influences of astronomical phenomena such as precession and the perturbations of the moon's orbit (Russel, Dugan & Stewart 1926: I: 286-290). The following table is taken from McCaw (1924. 120).

TABLE II.

METHOD	OBLATENESS OF SPHEROID.	AUTHORITY.
Geodetic.	1/297·0 ± 0·5.	Hayford, J. F.
Gravimetric.	1/297·4 ± 1·5.	Bowie, W.
Precession.	1/295·98 ± 0·2.	de Sitter, W.
Inequalities of Moon's motion.	1/293·5 ± 0·5.	Brown, E. W.

The results of these geodetic operations, geophysical methods and astronomical observations show very close agreement indeed, and jointly establish within narrow and precise limits the exact geoidal form and magnitude. But their highly technical character, involving the use of expensive instruments, the exercise of elaborate precautions to achieve and preserve accuracy, the systematic co-ordination and correlation of observations, the reduction of lengthy and complicated mathematical calculations, and finally, the symbolic representation of the resultant expressions; prevent them from providing a ready and convincing argument as to the form of the earth to any but the initiated, who naturally need no conviction. Although only a relatively small fraction of the total area of the globe has so far been geodetically examined, it is already clear that the geoid does not differ greatly from an oblate spheroid, and the assumption of an ellipsoid of three unequal axes is not at present considered useful (de Graaff Hunter 1926: XXX: 167). For certain areas of the continental masses it has been possible to represent the departure of the geoidal surface from the selected oblately spheroidal figure by means of geoidal contours (Hosmer 1919: 187).

At the meeting of the International Union of Geodesy and Geophysics held at Madrid in 1924, the figure of the earth as determined by J. F. Hayford in 1909 was adopted with very slight modifications (Lambert 1926: 242) as the International spheroid. Its elements are the following (de Graaff Hunter 1926: XXX: 167).

Equatorial radius	6,378,388 ± 18	metres
Polar semi-diameter	6,356,909	metres
Reciprocal of flattening	297·0 ± 0·5	

Recent remarkable developments and expansion in land, sea and air transport, attended by the broadcast issue of many informative, instructive and inviting circulars and illustrated periodicals (like the International Official Steamship and Airways Guide, published monthly), provide, not only incentive to travel, but ample data of distances, times and fares between different centres all over the world. Thus, in this Twentieth Century, the man in the street is furnished with the means necessary to make a simple, easy and interesting comparison of these facts and data, and thus build up for himself a concrete idea of the earth's form and size. Table III enables such a comparison to be made. After stating the inclination of the great circle course on a spherical globe to the mid-track meridian, the distances between the named places are given in nautical miles:—

(a) as traversed by modern transport in direct transit on the actual earth: and, in the other columns, the shortest possible distance on an earth of the form of

(b) a flat wheel, or the side of a cylinder of considerable but undefined thickness, the centre of the side of which is the North Pole with the Antarctic regions forming the rim:

(c) a double-sided disc, whose circumference is represented by the Equator:

(d) a double-ended cone, whose greatest circle is equal to the Equator, and whose slant sides are each equal to 90° of latitude: and

(e) a sphere of radius 3437·99 nautical miles, or 3958·89 statute miles.

Study of the facts given in table III should convince anyone that the only possible simple figure that in any way closely fits the distances recorded by transportation companies, to whom distance, time and fuel consumption are all-important considerations, must approximate to a sphere of

TABLE III

[ABLE OF THE SHORTEST DISTANCES BETWEEN SPECIFIED PLACES ON THE SURFACES OF EARTHS OF DIFFERENT FORMS.

ϕ	λ	Place to.	ϕ	λ	Bearing of Mid-route.	Actual Amount.	Flat Wheel Earth.		Two-Sided Disc Earth.		Conical Earth.		Spherical Earth.	
							Amount.	%	Amount.	%	Amount.	%	Amount.	%
° ′	° ′		° ′	° ′	Degrees.	N.mls.	N.mls.		N.mls.		N.mls.		N.mls.	
33 56 S.	18 29 E.	Liverpool	53 25 N.	2 59 W.	345	6,080	3,523	58	3,336	55	5,318	87	5,359	88
74 7 N.	93 14 W.	Port Nelson	57 2 N.	92 26 W.	179	1,042	655	63	655	63	1,025	98	1,025	98
57 2 N.	92 26 W.	New Orleans	29 58 N.	90 3 W.	176	1,672	1,040	62	1,040	62	1,626	97	1,627	97
29 58 N.	90 3 W.	Guayaquil	2 12 S.	79 51 W.	155	2,226	1,334	60	*		1,995	90	2,017	91
2 12 S.	79 51 W.	Valparaiso	33 2 S.	71 39 W.	166	1,981	1,318	67	1,318	67	1,890	95	1,906	96
33 2 S.	71 39 W.	Cape Horn	55 58 S.	67 17 W.	173	1,610	963	60	963	60	1,382	86	1,388	86
77 40 N.	104 15 E.	Chita	52 4 N.	113 15 E.	174	1,737	990	57	990	57	1,541	89	1,549	89
52 4 N.	113 15 E.	Peiping	39 54 N.	116 28 E.	170	782	476	61	476	61	736	94	742	95
39 54 N.	116 28 E.	Hongkong	22 17 N.	114 10 E.	186	1,129	681	61	681	61	1,061	95	1,063	95
22 17 N.	114 10 E.	Batavia	6 8 S.	106 48 E.	194	1,788	1,160	65	*		1,752	98	1,758	98
6 8 S.	106 48 E.	Fremantle	32 3 S.	115 44 E.	162	1,693	1,186	70	1,186	70	1,609	95	1,633	96
64 20 N.	165 0 W.	Vancouver	49 17 N.	123 8 W.	123	2,167	1,056	49	1,056	49	1,270	59	1,599	74
49 17 N.	123 8 W.	Honolulu	21 18 N.	157 52 W.	226	2,419	1,618	67	1,618	67	2,076	86	2,321	96
21 18 N.	157 52 W.	Suva	18 18 S.	178 26 E.	212	2,783	2,544	71	*		2,556	92	2,652	95
18 18 S.	178 26 E.	Sydney	33 52 S.	151 18 E.	241	1,735	2,379	136	944	54	1,575	91	1,732	100
48 50 N.	2 20 E.	Bucharest	44 28 N.	26 5 E.	105	1,220	704	58	704	58	733	60	1,008	83
44 28 N.	26 5 E.	Peiping	39 54 N.	116 28 E.	93	4,082	2,604	64	2,604	64	2,774	68	3,812	93
39 54 N.	116 28 E.	Yokohama	35 26 N.	139 39 E.	104	1,822	824	45	824	45	850	47	1,130	62
35 26 N.	139 39 E.	Honolulu	21 18 N.	157 52 W.	105	3,394	2,495	74	2,495	74	2,642	78	3,351	99
21 18 N.	157 52 W.	San Francisco	37 49 N.	122 29 W.	63	2,091	1,533	73	1,533	73	1,719	82	2,078	99
37 49 N.	122 29 W.	New York	40 43 N.	74 0 W.	86	2,292	1,601	70	1,601	70	1,630	71	2,230	97
40 43 N.	74 0 W.	Paris	48 50 N.	2 20 E.	83	3,293	2,158	66	2,158	66	2,278	69	3,149	96
33 56 S.	18 29 E.	Melbourne	37 50 S.	144 59 E.	89	5,814	8,622	148	3,707	64	4,205	72	′5,563	96
37 50 S.	144 59 E.	Wellington	41 17 S.	174 46 E.	98	1,489	2,556	172	1,002	67	1,019	68	1,386	93
41 17 S.	174 46 E.	Valparaiso	33 2 S.	71 39 W.	87	5,061	8,161	161	3,395	67	3,766	74	5,029	99
33 2 S.	71 39 W.	Buenos Ayres	34 36 S.	58 22 W.	100	695	1,100	158	502	72	506	73	668	96
34 36 S.	58 22 W.	Cape Town	33 56 S.	18 29 E.	88	3,850	5,923	154	2,657	69	2,773	72	3,709	96

NOTES.—The distances and percentages for the flat earth (wheel or disc shaped) are based on an equator of 21,600 nautical miles, so that the distance from either pole to the equator is 3,438 nautical miles.

If the meridian distance from the pole to the equator is taken as 5,400 nautical miles, the equator on a flat earth will measure 33,929 nautical miles, and the distances and percentages in columns 9. 10, 11 and 12 must be multiplied by the factor $\frac{\pi}{2}$ or 1·571 (approx.).

*Owing to the short time available it has not been possible to calculate these distances involving places on opposite sides of the disc except for Liverpool and Cape Town.

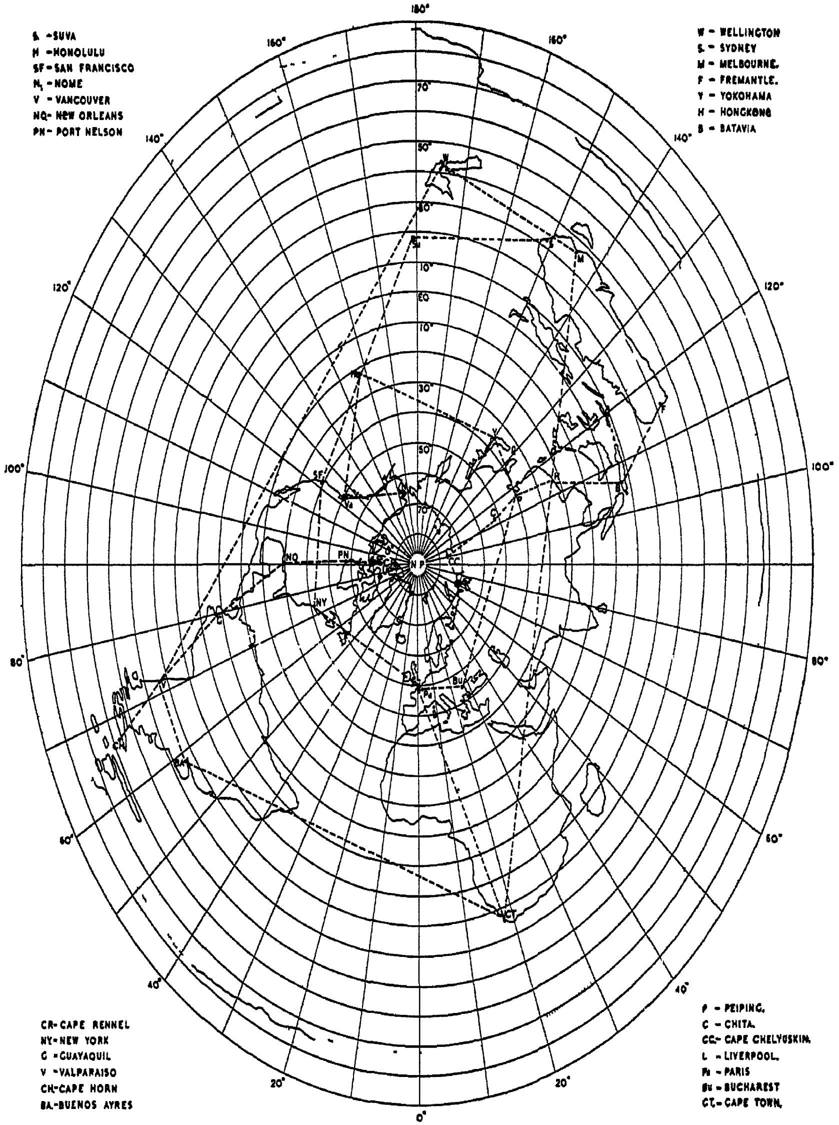

Figure 3a. (Scale 1/94,000,000. See note to Table III.)
Flat "wheel" Earth.

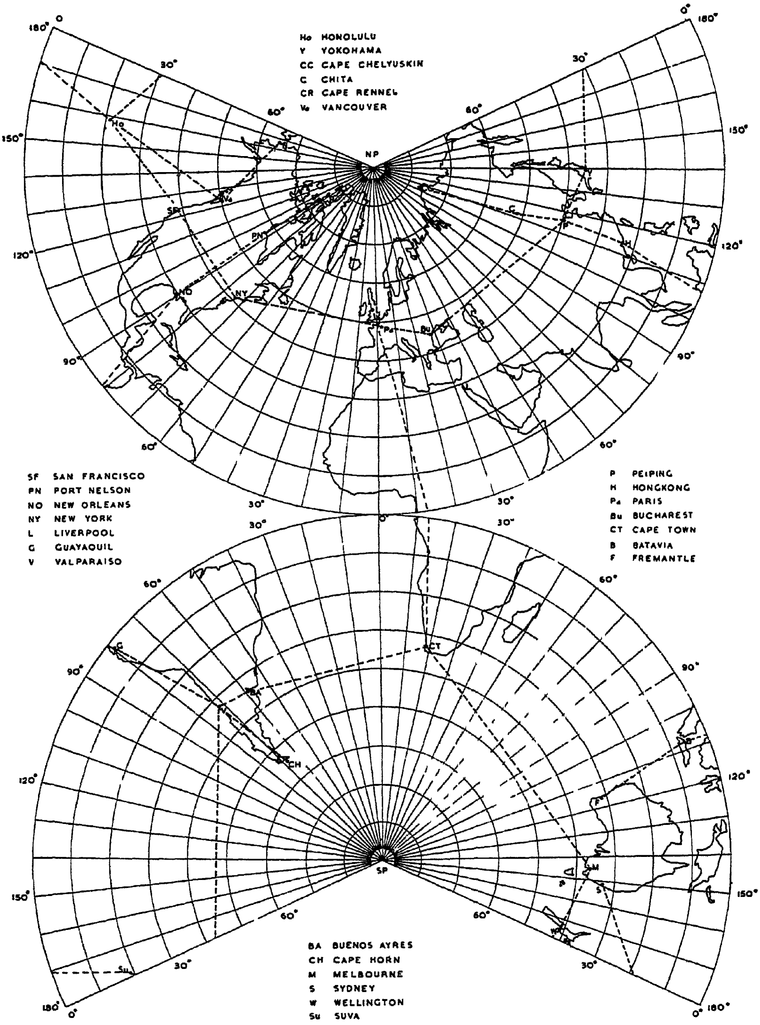

Figure 3b. (Scale 1/94,000,000.)
Earth represented on a Double-ended Cone

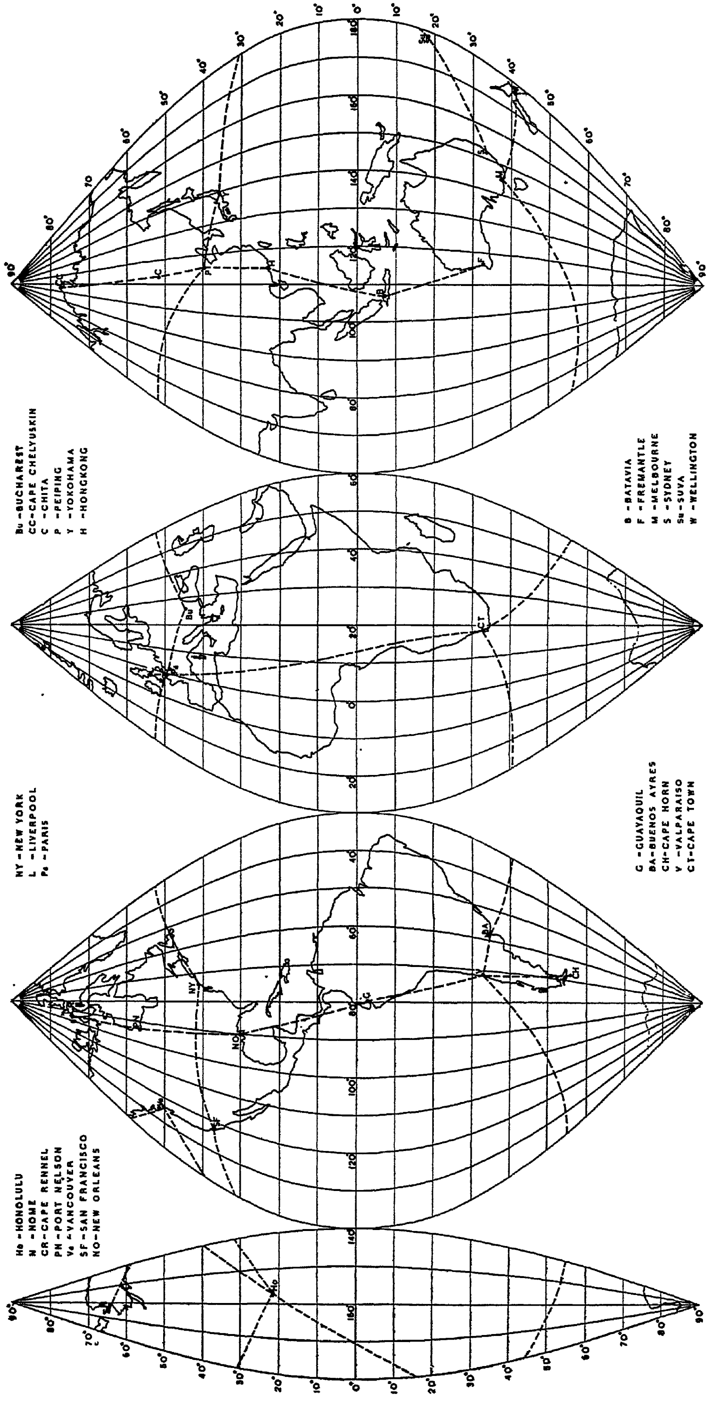

Figure 3c. (Scale 1/94,000,000.)
Globular Earth on Sanson Flamsteed's Projection (interrupted).

a size very nearly that given by Eratosthenes. The three accompanying diagrams (Figures 3 a, b, and c) illustrate these facts and are all drawn to the same scale.

9. Modern Views on Earth Motions.

The translatory motion of the earth is inextricably linked up with its globular form, and little can be added to what has already been stated on this subject.

The rotation is a much more satisfactory motion to discuss. In addition to its undoubted value as an abstractly speculative argument of great simplicity, and therefore of considerably enhanced probability, in comparison with alternative explanations, in accounting for such common phenomena as the varying length of daylight, darkness and twilight, and particularly the increase in twilight in winter as well as in summer in high latitudes as compared with the equinoxes, the earth's rotation is susceptible to experimental demonstration.

In 1802, Benzenberg of Hamburg (Blink & Boerman 1932: 26) demonstrated the eastward deviation of falling bodies owing to the rotation of the earth under them during their time of descent. In 1831, improved technique in a repetition of the experiment in an abandoned mine shaft in Saxony, showed that objects at that latitude deviated a distance of 1·12 inches in a descent of 520 feet (Gregory 1901: 192 & Joos 1934: 223).

Foucault's famous pendulum experiment performed at the Pantheon, Paris in 1851, showed clearly the uniform rotation of the globular earth. Repetitions carried out at different places show:—

(i) the rate of rotation of the plane of oscillation of the freely swinging pendulum to remain constant throughout each experiment:

(ii) the time occupied in making any definite fraction of a complete rotation of the plane of oscillation to vary precisely as the sine of the latitude of the place of observation:

(iii) the direction of rotation of the plane of oscillation to be in the opposite sense in each of the northern and southern hemispheres. In the northern hemisphere this direction is clockwise, in the southern, the reverse, while on the equator the vertical plane of oscillation remains constant. The experiment thus proves the rotation of the globular earth from west to east everywhere.

Foucault's less well-known experiment with a gyroscope (Barlow & Bryan 1923: 321), conducted in 1852, gives abundant confirmation of the correctness of his previous conclusion. When started with its axis pointing towards a certain star, the gyroscope changes its direction relative to the earth so that it continues with its axis pointing to that same star throughout the experiment. By taking cognizance of this fact and making due allowance for it in the gyroscopic compass, there have been designed for use in steel ships three varieties of a most valuable modern instrument of navigation—the Anschutz, the Sperry and the Brown gyrocompasses—each of which possesses a very much stronger directional force than that inherent in the best magnetic compass (Brown 1930: 216-223). The gyroscope also forms the basis of that invaluable instrument in long distance air navigation, the automatic pilot.

Modern artillery practice is an exact science. The trajectory of a shell in transit through the air is appreciably affected by the rotation of the earth beneath it. This is particularly the case when long range ordnance are used, such as the German fifteen inch gun which bombarded Dunkirk during the war of 1914-1918, from a distance of twenty-eight miles, or the more famous " big bertha " guns, that projected their shells a distance of seventy-six miles to reach Paris, through being elevated fifty-five degrees above the horizontal, so that much of their projectile's course was at a height of ten, or maybe as much as twenty-four, miles (Star 1940: 23rd March) above mean sea level (Bethell 1926: XXIX: 227). In such cases it is only by the careful application of calculated corrections for the earth's speed of rotation, as well as for its curvature and for the prevailing meteorological conditions, that the target can be even approximately covered by the zone of fire, which is about two miles long by three-quarters of a mile wide.

Coming to geographical and meteorological facts, the explanations of the circulations of the atmosphere given by Hadley (1735), Immanuel Kant (1756), William Ferrel (between 1853-1861) and M. F. Maury (1870-1892), and the modern analysis of the actual wind experienced into its geostrophic and cyclostrophic components, by which means its relation to the isobars on weather maps is understandable, depend solely upon these fundamentals. Similarly, the deflections of ocean currents and of river courses have been accounted for. Besides the departure of the earth from a sphere, the irregular distribution and triangular shape of continental outlines, and the antipodal positions of continents and oceans, have all been referred to at various times by scientists, as the effects of a rotating globular body constituted of heterogeneous material (Steers 1932: 3-5).

The division and recording of time, and its varying distribution over the earth's surface; the phenomena of precession of the equinoxes, nutation, eclipses and tides; the many aspects of terrestrial magnetism and wireless communication; the periodical recurrence, with diverse intensity, of the four seasons; the general uniformity of climate since the earliest geological times, with its superposed regular and irregular changes, including ice-ages, mild inter-glacial periods, and its shorter pulsations and fluctuations, experienced at different times in the many parts of the earth's surface; are each and all best, most satisfactorily and adequately explained on the basis of a globular earth, rotating on its own axis once every twenty-four hours and revolving around the sun in an elliptical orbit once a year, together with the moon and other planets, and all mutually influencing one another.

Although no reference is made to the several recent attempts to detect the actual motions of the earth through " absolute space," in any of the works on general astronomy that I have consulted, we cannot leave our subject without alluding to these important contributions to our knowledge of physical science and of the universe. Following the original experiment, carried out in Berlin in 1881 by A. A. Michelson, most of these attempts have been made with the object of determining the velocity and direction of motion of our planet through a postulated fixed, cosmic, all-pervading, imponderable and luminiferous ether (Einstein 1921: 15 & 52), by considering the influence of such motion on the propagation of light (Haas 1923: 124). and on electric and magnetic fields (Grimsehl 1935: V: 439 & 443) at the earth's surface. To the great surprise of physicists very nearly all of these experiments have " satisfactorily demonstrated a null effect to the order of the experimental error " (Tolman 1934: 14). Those attempts, like the Michelson-Morley-Miller experiment carried out in 1925-6 (Miller 1926: 433-43, & 1933: 203-42), which gave results, claimed to be real, and amounting to approximately five per cent. of the values sought and expected; when repeated by others, as by Kennedy in 1926 (Tolman 1934: 13) and by G. Joos in 1930 (Joos 1934: 227), using every care and refinement, are not found to yield in any way comparable results. Indeed, it is extremely doubtful whether any effect of ether-drift would be realized, or measurable, if the Michelson-Morley experiment were correctly oriented and performed in either a mine-cage steadily descending the shaft of the deepest mine, or in a lift falling freely with ever increasing velocity under the action of gravity (Eddington 1928: 111), or in the cabin of a spitfire aeroplane diving at a velocity of six hundred and fifty miles an hour, or in a chest being pulled upwards "with a uniformly accelerated motion" to the uttermost confines of space (Einstein 1921: 66).

In 1925, Michelson and Gale, working along similar lines investigated the rotational motion of the earth, by having the arms of the apparatus—originally in the form of a right angle and later of a Greek cross—as unequal in length as feasible instead of as equal as possible (Grimsehl 1935: V: 435). Partially based on the Sagnac experiment of 1914 (Grimsehl 1935: V: 432-5; & Joos 1934: 450-1), this "optical analogue of the Foucault pendulum experiment" gave small but positive results, the observed shift of the interference fringes being ·230, as compared with a predicted shift of ·236 (Birkhoff 1925: 83-4). In discussing the experiments of Michelson-Morley and Michelson-Gale, Joos (1934: 451) states "It seems absurd that the ether could be carried along by the earth completely in translation and not at all in rotation."

In an attempt at an "experimental establishment of the relativity of time," Kennedy and Thorndike in 1932 (Phys. Rev. XLII: 400-18) considerably improved upon the Michelson-Gale experiment. They devised a special source of light emitting through the apparatus only the most suitable portion of the spectrum, the mercury line of wave length λ 5461; their interferometer was of great stability; while they introduced increased refinement into the technique of measuring displacements in the interference patterns by using photographic methods with very elaborate precautions. Yet, in the words of the authors, the resultant velocity of "10 ± 10 km. per sec., in view of relative velocities amounting to thousands of kilometers per second known to exist among the nebulae. . . . can scarcely be regarded as other than a clear null result . . . of the same order of precision as that of the Michelson-Morley experiment." From the results of this, the only investigation in which a quantum phenomenon is shown to conform to Einstein's theory, the authors successfully derive the Lorentz-Einstein transformations.

Similarly, in the field of research concerned with the electrodynamics of moving bodies, the Trouton-Noble experiment of 1904 (Joos 1934: 447-8),—since frequently repeated by Tomaschek—using the turning moment acting upon a suspended parallel-plate condenser—a principle giving much greater sensitivity than the Michelson-Morley experiment—showed that even at a height of 3,500 metres above sea level there is no effect corresponding to an ether-wind of more than half-a-kilometre per second (Grimsehl 1935: V: 439 & 443).

It may seem strange that the apparently obvious conclusion from these experiments—viz. that the earth is stationary—neither finds favour with, nor receives support from the many investigators interested in this matter. But calm and logical reflection leads definitely and inexorably against such a conclusion. Instead, these null results are being used as a common basis for the discovery of further hidden secrets of nature and of the universe. Briefly stated, the interpretations of these experimental results by the leading physicists and mathematicians appear to be:—

(a) " There is certainly a velocity of the solar system relative to the fixed stars to be added to the orbital velocity of the earth. and probably a very large velocity of the galaxy with respect to the extra-galactic systems " (Joos 1934: 228).

(b) " Experiment has decided against . . . the existence of a stationary medium carrying light; i.e. the existence of a cosmic ether or absolute space is disproved " (Joos 1934: 227).

(c) " The velocity of light between two points on the earth's surface is the same whatever relation the direction of the line joining the points may have to the direction of the earth's orbital motion " (Schuster 1911: 107 & Reichenbach 1932: 135).

(d) " Since all the phenomena of light and of electromagnetism are believed, on almost incontrovertible evidence, to be in accordance with the hypothesis of relativity, it is necessarily impossible to determine absolute velocity by optical or gravitational means" (Jeans 1926: XXXI: 328-9).

Thus all the apparently indicative evidence, which from time to time has been proffered to establish that the earth is a flat, steadfast and stationary solid, has failed to withstand the critical analysis of unbiased science. And though the conclusion that our planet is round, and that it rotates and revolves must still depend upon experiments, arguments and observations originally made and given before the

Twentieth Century dawned; nevertheless their number is so great, their cumulative effect is so strong and their reasonableness so impelling that none, when cognizant of them, will lightly essay to prove the contrary.

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ECONOMIC AND DOMESTIC IMPLICATIONS OF PLANT DISEASES IN SOUTHERN RHODESIA.

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In considering the economic and domestic implications of plant diseases in Southern Rhodesia, I will first of all outline briefly the principal diseases affecting crop plants in the Colony, and then analyse the manner in which the incidence of these diseases affects our national economy. For the purposes of this paper the following crops are considered of major importance: tobacco, maize, small cereals, fruit and vegetables. Some of these are of direct financial benefit to the Colony, whilst the value of others is more nutritional than financial and is concerned with maintaining the health and vigour of the population. We must also consider the bearing of plant diseases on the distribution of the rural and urban populations. as this is often great, and finally, a discussion of the developments of plant disease control will show how much responsibility rests on the present generation for the economic well-being of its children.

I shall deal fully with the diseases affecting tobacco, as this crop is in the front rank of agricultural produce and has a marked effect upon the economic and domestic life of the Colony. The diseases of most interest are angular spot and wildfire caused by bacteria; frog eye, brown spot and mildew caused by fungi; and mosaic, leaf curl and rosette caused by viruses. All these diseases are of wide distribution, but their incidence is controlled by climatic conditions and farming methods. For instance, angular spot and wildfire may be regarded as endemic, but whereas the former makes its appearance with utmost regularity on farms where tobacco has been cultivated for a number of years, the latter only assumes epiphytotic proportions in the odd years when meteorological conditions are ideal for its development. The difference in behaviour of these two diseases is responsible for an idea prevalent amongst tobacco growers that wildfire in Rhodesia is not the same disease as the one which is responsible for its popular name, and that the organism occurring here is merely a mild strain of the American parasite. This idea has been common for many years despite my insistence that wildfire in Rhodesia must not be treated as a disease of no account, but I think a change of opinion has occurred among growers after their experiences during the past season. Following a very wet December, wildfire appeared all over the Colony, on new farms as well as on old. Its development was undoubtedly due to the favourable climatic conditions, but the reason for its wide distribution, especially on new farms, is still something of a puzzle. Its presence on the older farms is in many cases easily accounted for, as although the disease had been recorded from time to time for many years, its existence was denied by the growers on account of their crops not being completely destroyed. The failure in the past of growers to admit the danger was this year responsible for a mild panic when the wildfire epiphytotic occurred; I was even accused of having introduced a new form of wildfire, which I spread round the countryside on my visits to tobacco growers! I am sorry to say that many farmers destroyed the whole of their early plantings and thereby incurred considerable financial losses.

The widespread development of the disease in the past season means that much of the tobacco land of the country is now infected and we must expect wildfire to appear next season in many crops. But the publicity which the disease has now obtained has had some beneficial effects, which I think will compensate in the future for the damage inflicted this year. For instance, many growers, as an emergency measure, decided to spray their crops in the field and the benefit obtained from this operation is now generally appreciated; I think it will not be long before field spraying in some form or other is adopted as a routine practice. Furthermore, most growers are now keenly alive to the possible appearance of wildfire on their farms and are prepared to take immediate action for its suppression. Many farmers are seriously considering the introduction of definite crop rotations, in place of the present practice of growing tobacco for two years and then allowing the land to fallow. The wildfire scare of the past season will do much towards increasing the yield per acre of tobacco by inducing growers to adopt more stringent measures of disease control, and I also hope to see an increase in the quality and value of the crop, as distinct from its bulk, thereby bringing in additional revenue to the Treasury at a time when it is urgently needed.

The reaction of tobacco farmers to angular spot contrasts very much with their attitude to wildfire. As I have said, angular spot makes its appearance with regularity on many farms and is regarded with little apprehension. It is now looked upon as almost inevitable. But angular spot, to my mind, is year by year far more destructive than wildfire, and where crops are subjected to heavy storms very serious damage may result. Yet this disease can be entirely eliminated from crops by those who realise its seriousness and apply control measures at the earliest possible moment. This is now being done by many growers. Seed disinfection, adequate spraying of seed-beds, together with judicious priming, ensures freedom from angular spot in most cases, but where climatic conditions are favourable for the development of the disease, these methods have to be supplemented by field spraying. As yet these methods have not been generally applied with strict precision and angular spot regularly takes a heavy toll of the crop. Control measures are being applied more thoroughly this season and more growers spray their crops in the field; so we have reason to hope that the losses caused by angular spot will be much reduced in the near future.

Two fungus diseases, frog eye and brown spot are undoubtedly of great economic importance to the tobacco industry. Brown spot is more commonly known in the Colony as Alternaria and in the Union as red rust; it is due to the fungus *Alternaria longipes*. Frog eye, due to *Cercospora nicotianae*, is still not fully understood by new growers The field spot is well known but the appearance in the barns of black spots on the leaves is not always associated with the fungus in the field. Barn spotting is, however, brought about by spores of the fungus, which, during the process of reaping or by agency of the wind, become distributed over the leaf surfaces and germinate during the early stages of curing setting up small areas of infection. These turn black when the temperature is raised. Black barn spot is extremely prevalent and is responsible for the ruination of a large proportion of total leaf each year. Generally speaking, it can be considered as a disease of starved leaf and its prevalence in the Rhodesian tobacco crop is associated with delayed "priming." It is becoming more and more fully realised that if frog eye control measures are adopted and the thin, papery, lower leaves, lacking in body are removed from the plants during their early stages of growth, not only is the disease controlled but the quality of the resultant crop is greatly enhanced. The trend of tobacco culture in recent years is, therefore, to remove the lower leaves before disease is out of control and to take the crop from higher up the stem. This system not only eliminates frog eye spotting but also affords protection against brown spot.

In contrast to frog eye, brown spot is essentially a disease of heavy bodied leaf, or rather it is only dangerously destructive to this type of tobacco. The development of the fungus is also largely dependent on climatic conditions, being favoured by high temperatures. Severe damage to crops is, therefore, more apparent in areas of comparatively low elevation where temperatures are higher than on the high veld and epiphytotics occur during the wet periods in late January and February, particularly where tobacco is grown on heavy soil. Development of the disease is assisted by the popular habit of topping plants low in order to increase body in the leaf and losses of the top 4 or 5 leaves may occur if topping is done before a spell of wet weather. In extreme cases complete loss may result. The need for this low topping is due to the practice of allowing the lower leaves to remain on the plants until they commence to perish, thus exhausting plant food materials available for the upper leaves. If the plant is not topped low, all the harvested leaf is light in weight and deficient in essential oils and gums. If priming of the lower leaves is carried out several times in order to control frog eye disease, then it is possible to top the plant much higher, retaining the normal number of leaves (usually fifteen or sixteen) without losing any body in the leaf. In fact, it is becoming clear that this method of managing tobacco improves the quality of the leaf and there is evidence that with an equal number of leaves the yield is actually increased. Under these conditions the top leaves do not become coarse but ripen normally and show considerable resistence to brown spot, whilst the early removal of bottom leaves on which brown spot may be commencing to develop prevents the dissemination of spores and delays any suggestion of an epiphytotic until reaping is so far advanced that no serious damage can be done. There are indications that field spraying up to six weeks after transplanting also assists in the control of brown spot.

That brown spot is an economic menace to the tobacco industry was shewn during the 1938-39 season when heavy rains caused epiphytotics on most farms: the crop yielded an average of only 375 lb. of light bodied leaf per acre, the majority of the upper, heavy leaves being destroyed by the disease.

Mildew, due to *Erisyphe cichoracearum*, was at one time the most destructive tobacco disease in Rhodesia, but in recent years resistent varieties have replaced the old susceptible Hickory Pryor and the disease can now be considered as of little economic importance.

Virus diseases are of general distribution, the three most important being mosaic, rosette and leaf curl. Norval (1939: 2) estimates that 7 per cent. of mosaic infected plants may occur on well managed farms but considers that many crops shew as much as 20 per cent. No accurate survey has been made of mosaic throughout the Colony, but the depreciation in value of leaf due to this disease is well known. Many growers must lose from £400 to £500 a season on a 100 acre crop due to inadequate control of mosaic. These losses are prevented by such simple methods as hand-washing whilst plants are being handled and allowing mosaic symptoms to appear on all infected plants before the first priming, to prevent the transmission of the virus to healthy plants. Where carried out efficiently these methods are entirely successful, but mosaic continues to take a heavy toll from the crop each year.

Rosette is a new problem. The disease was described in 1936 by Wickens (1938: 181) who demonstrated its transmissibility by the vector *Myzus persicae*. It is severe on late planted tobacco, which may show 100 per cent. infection. Its ravages are accentuated by the direct damage caused by the aphid vector and the sooty mould which follows heavy insect infestation.

Rosette this season has been very severe in certain districts, but conditions have been exceptionally favourable for an epiphytotic. Aphids appeared relatively early in the season and infested seed-beds. A drought in most parts of the Colony, or at least those parts where the disease developed widely, caused the last tobacco lands to be planted exceptionally late. This very late tobacco was subjected to severe infestation by aphids, which were in an unusually high state of infectivity.

It has been represented to me that rosette may become the greatest menace with which tobacco has yet been faced in Rhodesia, but this is not borne out by my observations The severe damage caused this year was confined to a few districts only; often to individual farms. The most widespread infection always occurred in exceptionally late planted tobacco and although most growers attempted to rogue their lands, insufficient attention was given to the relatively few rosetted plants in the early fields. These early plants acted as reservoirs of infection for the later crop and as aphids increased in numbers, more and more picked up the virus, so that in the end the vast majority of the aphid population must have been infected. The very late planting of the final crop exposed the tobacco to conditions of infestation which do not normally occur. It is my opinion that much of the damage done this year can be attributed to lack of aphis control in seed-beds, inadequate rogueing of the first and second plantings, and, finally, the exposure of the last plantings to exceptional seasonal conditions. Rosette disease is potentially a serious menace to the tobacco crop, but I think that it can be controlled by relatively simple farming methods such as seed-bed spraying, rogueing in the lands and a rigidly enforced "close season." I do not consider its economic importance to be as great as that of either frog eye or brown spot.

Leaf curl, of which the insect vector is the white fly *Bemesia rhodesiaensis*, was at one time regarded in the same light as rosette is to-day. Legislation, enforcing the destruction of growing tobacco after August 1st, has been most effective in eliminating sources of infection and controlling white flies, so that the disease is now of minor economic importance.

Having considered in some detail how losses in the tobacco crop may be brought about by various diseases, I will now attempt to summarise in round figures the average financial loss to the grower. It is very difficult indeed to estimate with accuracy losses directly due to plant diseases, but I do think the figures which I shall now give are at least a reasonable approximation. I shall work on a basis of an average of 15 leaves to a normal plant, a crop of 30 million lbs., a unit acreage of 100 (the average acreage planted per registered grower is just short of 100) and a selling price of 1/- per lb. The cost of production is generally accepted as about 6d. per lb. Now if one leaf per plant is destroyed by leaf spotting diseases, the loss from this source is approximately 7%. A reasonable figure for reduction in value caused by mosaic is 5%, whilst rosette and leaf curl together probably destroy a further 5% of the crop. Thus from these causes alone we may assume that 17% of the crop is lost annually. If we add another 3% to this for losses due to minor diseases, such as root and stem rots, soil deficiencies and barn rot, we can base our further calculations on an average loss of 20% per annum.

Now if this proportion could be saved, the 30 million lb. crop would be increased to 37½ million lb., giving an increase in value, at 1/- per lb., of £375,000. As half this would be increased profit, the actual amount that the tobacco growers would gain by eliminating the diseases at present recognised in the country would be £187,000. As there are 700 registered growers in the Colony this figure represents an increase of £267 profit per grower.

Let us now consider the costs of control measures. We have found that by using hand-operated knapsack pumps, fitted with fine jets and a whorl type of nozzle, producing a mist-like spray, effective control of leaf spotting diseases may be obtained in the seed-beds by applying copper fungicides at the rate of 2 gallons per bed per spraying. This is usually repeated 5 times, and the total cost for spraying seed-beds sufficient to plant 100 acres is approximately £6 for proprietary copper sprays and £3 10s. 0d. for home-made Bordeaux mixture. In the field we find that 10 to 15 gallons per acre per application, in conjunction with suitable priming, will control angular spot, wildfire, brown spot and frog eye. Generally speaking, three applications are sufficient and the cost of materials amounts to between £15 and £22 10s. 0d., so that the total cost of spraying material for the whole crop of 100 acres ranges between £18 10s. 0d. and £28 10s. 0d. for the season. Labour costs must, of course, be added to this but these vary considerably according to farm management.

It is obvious that the total cost of spraying is very small compared with the additional profit which can be obtained by efficient plant disease control, but we must also take into account the severe monetary setback which may overtake the individual grower, who is unfortunate enough to be unable to control an outbreak of say angular spot, wildfire or brown spot. Any one of these diseases is capable of causing almost complete destruction and a good many instances could be cited of growers who have been financially ruined by one bad season. In other cases, successive outbreaks of disease, year after year, have produced the same effect. Heavy losses of leaf cause a diminution in the grower's income and the consequent reduction in spending power usually results in the curtailment of essential agricultural practices for the maintenance of soil fertility and "health." With a decrease in the fertility of the soil comes an increase in the incidence of diseases and further reduction in income. Contour ridging and organic manuring can no longer be undertaken and soil erosion commences. No money is available for stumping, so that old lands are replanted to tobacco. The use of fungicides is discontinued. Our sandy tobacco soils, which are dry all through the winter, make an ideal medium for the survival of the bacteria of angular spot and wildfire, whilst undecomposed fragments of a previous crop maintain the fungi of frog eye and brown spot in active form. A time soon comes when it is uneconomic to plant tobacco, the grower goes out of production and the farm is abandoned to the ravages of wind and storms.

But what of the grower and his family? In many cases they migrate to the towns because their experience has embittered them to the farming life or because they have insufficient capital to make a new start. The children are brought up to regard farming as a "mug's game" and farmers with contempt, so that the breach between town and country is widened. If we investigate the stories of those families who have moved from country to town in Rhodesia. we shall find that in a large proportion of cases, tobacco diseases were the initial cause of their financial failure.

There is only one type of disease which can be considered to be of economic importance affecting maize in the Colony. This can be classed as ear rot. Several fungi are concerned, being the same as those recorded from other maize growing countries. The most important are *Giberella saubinetii*, *G fugikuroi* and its variety *subglutinans* and *Diplodia zeae*. Recently, *Nigrospora* has been found causing the black bundle disease. For the sake of convenience and to avoid confusion among growers I have grouped the diseases caused by these fungi under the one name "Diplodia." Their etiology is similar and control measures are the same, so that I will deal with them as a single entity. The symptoms of Diplodia are well known, consisting of ear rot, stem rot, and seedling blight, and the disease is seed-borne. The degree of Diplodia infection in the maize crop varies considerably from year to year, being greater in wet than in dry seasons, and the damage done is particularly severe when late rains cause the ripe cobs to dry out slowly. No reliable figures have been obtained of the total losses caused by Diplodia, and I will not attempt to give a figure. They are, however, substantial and unfortunately not entirely obvious. The amount of mouldy grain in the crop could be ascertained without difficulty but reduction in yield caused by stem rot and seedling blight originating from diseased seed is not easy to estimate, although there are indications that seedling blight can bring about a reduction in stand of over 10%.

Control of the disease is divided into two parts, namely, prevention of ear infection by methods of field hygiene and the elimination of seed contamination by selection and disinfection. The disease is so well established in the main maize belts of the Colony that the elimination of cob infection is, at the moment, an impossibility, but recent developments suggest that a gradual diminution of the disease may be accomplished slowly, year by year, until the losses arising from mouldy grain may be much reduced. Until last year, satisfactory methods of disposal of infected crop residues could not be devised, for we had no exact knowledge as to whether the fungi could exist after being eaten by cattle, or could grow and fruit upon kraal manure. Miss Stiemens (this journal, **36**, 220) has recently shown at Pretoria University that none of the serious parasitic fungi survives digestion by cattle and that antagonistic organisms destroy them in fresh kraal manure. It would appear, then, that a large bulk of the residual maize trash can safely be fed to cattle and the resultant manure utilised for preparing compost. We have no evidence that infected stalks, in the quantities fed to Rhodesian cattle, are deleterious to the animals.

With regard to seed infection, the position is most unsatisfactory, a very high percentage of diseased grains being present in most samples sold. This can be accounted for by the popularity which cheap seed has attained in recent years, inducing farmers to give up selecting their own seed in favour of that produced and sold by a few large growers. Field and hand selection have been reduced to a minimum, and the intense competition among maize breeders which used to obtain at Agricultural Shows has faded into insignificance. It would appear that a revival of the keen interest at one time shown in seed selection is the only remedy which will bring about an immediate improvement in the quality of the seed in the Colony. Seed treatment with mercury dusts is a cheap and effective way of overcoming the type of infection which is overlooked when seed is being selected, but it will not destroy the fungi present in obviously mouldy grains. Selection and disinfection must go hand-in-hand if full benefits are to be derived from the latter operation.

A further source of loss is due to planting on infected soils, and during the past wet season an unusually high percentage of barren plants, due to stem rot set up in the early stages of plant growth has been seen. There is only one method of reducing losses from this source, and that is by crop rotation, but the difficulty is experienced of finding suitable crops which will fit in with maize grown over large acreages. Green manuring has been practised for some time past but, so far, no suitable variety of cash crop has been found which will enable growers to obtain immediate economic returns from land put out of maize cultivation. Farmers are, however, beginning to realise that it is impossible to devise a satisfactory farm economy in which soil fertility is maintained and diseases reduced to a minimum unless rotations are practised on a much wider scale.

At the beginning of this address I stated that the value of some crops is more nutritional than financial, the reason being that these crops formed no important industry, or rather that they had not reached a stage of production when they could be exported.' I referred mainly to small cereals, fruits and vegetables. No one can deny that these crops are necessary in order to provide a balanced diet, and it is my opinion that we, in Rhodesia, do not consume enough of these products. In most families of moderate means fruit and vegetables are regarded as luxuries, whilst the products of small cereals, such as breakfast foods, are generally imported. The production of small cereals in Rhodesia does not as a rule meet local requirements, and the reasons for this shortage are varied. In the case of wheat, for instance, plant diseases must be held partly responsible for the small amount produced. Considerable damage is done by rust in most seasons, whilst loose smut and bunt are becoming increasingly prevalent. The crop, however, receives a Government subsidy and a relatively large number of growers are able to subsist on a non-economic output. If the money expended on the wheat subsidy were devoted to successful rust research, and the crop thereby increased to the export stage, a correspondingly high financial return would not be obtained, since all the surplus above local requirements would have to be sold on the world market. Under the conditions of present day economy, therefore, rust in wheat must be regarded as a blessing rather than a curse to Rhodesian growers.

The same, however, cannot be said for the diseases of fruit and vegetables. Generally speaking, supplies are irregular and in nearly all cases prices are high. Seasonal fluctuations are common, and it may be said that the shortages occurring in the towns are largely caused by the incidence of pests and diseases, which make their appearance every year. Very little attempt is made by growers to control these parasites and hardly any well devised control schedules are followed. Some effort is made to control the diseases of apples, but I know of no commercial orchards where a full spray programme is employed. With vegetables, half-hearted attempts are made to spray the crops with Bordeaux mixture, arsenate of lead and contact insecticides but these are usually applied at the wrong seasons, at incorrect dilutions and by means of indifferent pumps.

As a result of all this uncertainty of production, difficulty is found in marketing these essential foodstuffs in a regular manner, and as a consequence much of the Rhodesian produce is unable to compete with undergrade imported material. The Rhodesian public is therefore compelled to pay high prices for inferior products and consequently the consumption of fruit and vegetables, as compared with other countries, is low. As a result of the small turnover retailers say they are forced to keep prices up. So the vicious circle is complete. To give some idea of household purchases I can state a figure for expenditure on fruit and vegetables which I obtained whilst serving on a Committee investigating the cost of living for civil servants in the Colony. The monthly outlay by the average married couple with one or two children was between 15/- and £1 0s. 0d. When one considers that we have to pay 4d. and 5d. a lb. for peas, 10d. or 1/- each for cabbages, anything between 1/- and 2/- for fair sized cauliflowers, 4d. to 6d. per lb. for green beans, 2d. to 3d. each for apples, 3d. each for grape fruit, 9d. to 1/6d. each for papaws and so on, it is little wonder that fruit and vegetables are regarded as luxuries and not as foodstuffs essential to the healthy up-bringing of children.

From personal experience I can say that the climate of most of the settled parts of Rhodesia is such that a wide variety of fruits and vegetables can be raised with utmost ease, provided reasonable precautions are taken for the control of diseases and pests. In fact, market gardening in

Rhodesia is synonymous with insect and disease control. Improved methods of plant protection may be of great assistance in supplying the necessary foodstuffs to maintain the virility of the population.

Finally, we must look to the future. Not only must we endeavour to control those diseases which at present take a heavy toll of our crops, but we must guard against the introduction of even more serious diseases, the control of which may cost the rising generation millions of pounds. As in the case with all young countries, expenditure on essential services, such as quarantine facilities, must be restricted to the funds available, but I do think that the public can protect themselves against future losses by co-operating fully with the Government in efforts to exclude dangerous parasites. All too frequently objections to legislation are made on the grounds that this is Government interference, and personal prejudice is inclined to obstruct a long-sighted policy. Furthermore, members of the public, particularly individual gardeners, overlook the debts and burdens which they may be preparing for future generations by the introduction to the Colony of serious diseases, when they, perhaps unwittingly, evade the plant importation regulations by introducing in their pockets and baggage, seeds, cuttings and roots of plants from other countries.

I have endeavoured to show in this address that the control of plant diseases should not be considered as a specialised problem solely related to monetary profit and loss but is intimately concerned with the development of society. If it is true that the efficiency of a nation is dependent on the physical fitness of its individual citizens, then the plant pathological aspect must receive due consideration in the formulation of any social schemes.

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AFRICA AND THE ANCESTRY OF MAN.

BY

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In 1871 Charles Darwin in "The Descent of Man" expressed in characteristically cautious terms the following opinion:

> It is . . . probable that Africa was formerly inhabited by extinct apes closely allied to the gorilla and chimpanzee; and as these two species are now man's nearest allies, it is somewhat more probable that our early progenitors lived on the African continent than elsewhere.

To all scientific workers in the African field the conception thus tentatively put forward is naturally of singular interest. I propose therefore in this address to consider how far it has been supported by research during the intervening seventy years.

MAN AMONG THE PRIMATES.

The knowledge so far gained has consistently supported the general contentions of Darwin, that man shares a common physical ancestry with other animal types, and in particular, with those which Linnaeus, long before Darwin, had grouped with Man under the name of Primates. These comprise the lemurs or half-apes, the monkeys of the New and of the Old Worlds, and the anthropoid or man-like apes. While the anatomy of these diverse Primate types leaves no doubt that they are descended from a common ancestor (le Gros Clark 1934), the lemurs, including besides those of Madagascar the loris of Asia and the bush-baby (Galago) of Africa, must have become separated at a very early stage from the monkeys and apes. Of these two subdivisions of the Primates, the lemurs are much nearer to the generality of mammals. Midway between lemurs and monkeys stands the peculiar East Indian Primate known as the spectral tarsier, for which a special intermediate subdivision of the Primates, the Tarsioidea, has been established.

Of the monkeys and apes, the New World (South American) monkeys, including the tiny marmosets as well as such types as the spider and howler monkeys, must have been the first group to become separated, remaining in certain respects more primitive than the Old World monkeys and the anthropoid apes. These latter types share a number of features which indicate that they diverged from one another only after they had parted company with all the other Primates. The Old World monkeys, tailed and quadrupedal, include the macaques and langurs of Asia as well as the guenons, baboons and mandrills of Africa; the tail-less, quasi-erect and long-armed anthropoid apes comprise the gibbons and the orang-utan of Asia and the chimpanzee and gorilla of Africa.

The gibbons, small, slenderly built and extremely agile, possess certain features also present in the tailed monkeys but not in the other larger and more ponderous man-like apes. We may presume that these features were present in the ancestral apes after their divergence from the monkeys, and moreover, that the ancestral ape stock was small and in most respects gibbon-like. This stock split into two divisions, one giving rise to the modern gibbons, the other increasing in bulk and differentiating into the chimpanzee, gorilla and orang-utan.

Man shares the structural features common to the Old World monkeys and the anthropoid apes; in other respects he displays an overwhelming volume of correspondences with the latter group. For this reason most comparative anatomists have agreed with Darwin in concluding that man must have become differentiated from the anthropoid apes only after this group was already separate from the remainder of the Primates. Professor F. Wood Jones (1929), it is true, has argued that the ancestors of man were differentiated from the primitive Primate stock even before the separation of monkeys and apes. On such a view the spectral tarsier would probably be as nearly related to Man as any other Primate. This, however, can only be maintained by attaching inordinate importance to certain differences between man and the apes, and explaining away a vastly greater number of resemblances between them. An appraisal of all the evidence goes strongly against this view, and in favour of man's direct relationship with the anthropoid apes.

As Sir Arthur Keith (1923) and other investigators have shown, many structural differences between the man-like apes and the tailed monkeys can be associated with their different habits of movement. While the monkeys usually run and leap on all fours, the apes clamber in a partially upright position, or swing suspended by their arms (brachiation). The structural changes related to these distinctive habits have resulted, among other consequences, in the ability of the man-like apes to stand erect on their hind limbs in a way practically impossible to any other Primate. These structural peculiarities are found also in man, whose acquisition of them is explicable only if he passed through a stage in which he shared the climbing habits of the man-like apes. Such an apprenticeship to upright climbing seems to have been a necessary prelude to man's adoption of his upright standing posture.

Anatomically, man is nearest in some respects to the gibbons, in others to the larger apes, showing, according to Sir Arthur Keith (1934), more similarities to the African chimpanzee and gorilla than to the Asiatic orang-utan. The late Dr. H. F. Osborn (1928) considered that the separation of the human stock from that of the ape took place at least as far back as the cleavage between the gibbons and the larger apes. Most authorities, however, believe that after that cleavage man was differentiated from the large ape stock, though before that stock had entirely lost its ancestral gibbon-like features. Schultz (1930) suggests that the differentiation of Man took place before the ancestors of the living large apes were appreciably distinguished from one another, Gregory (1927) that it occurred about the time of the separation of the orang-utan from the African apes. The evidence assembled by Sir Arthur Keith and other investigators, however, indicates rather that, as Darwin supposed, man's ancestors diverged from the African apes after their separation from the orang-utan. This conception has been restated by Sir Arthur Keith (1934) in the following terms: "I therefore anticipate that the fossil remains of an anthropoid ape will be found one day—probably in Africa—which will serve as a common ancestor for man, gorilla and chimpanzee." We shall see later how near actual discovery has come to the fulfilment of this anticipation.

THE DIFFERENTIATION OF MAN.

The crucial point at which the ancestors of man diverged irrevocably from the apes was that at which they abandoned life in the trees for life on the ground, and so were able to extend from the forests on to the open plains. For the future of man the change to life on the ground was momentous, because the structural modifications established in the climbing apes provided the foundation for a posture unique among terrestrial animals, erect walking on the hind limbs. In this way the flexible grasping hands were set free from the task of supporting the body and could be turned to entirely new uses. This novel posture has brought about considerable anatomical changes, especially in the loins and pelvis, the leg and above all the foot. Such changes cannot have been the product of a few generations; they afford some measure of the time which has elapsed since the ancestors of Man descended from the trees.

Between man and the apes there are also significant differences in the form of the skull. In man the jaws are relatively much smaller; this is due in part to the differences in the form of the teeth, which are used not for biting and tearing as in the apes, but for grinding and chewing. On the other hand, the braincase is relatively much larger and greatly modified in form as a result of the greater size and complexity of the brain. Man's brain is his most distinctively specialised organ, although its fundamental plan corresponds with those of monkeys and apes. It is distinguished by its size, for in total bulk it is exceeded only by the brains of the whale and the elephant, but still more by the proportion which its weight bears to that of the body as a whole. The increase in size as compared with the ape's brain is not displayed equally by all parts of the brain, but is limited to certain regions, the so-called "association areas." These neither directly receive sensations from the exterior nor directly control the activities of the body, but their integrity is essential for the processes of thought and for their expression by speech or any other means. There are two of these areas, the prefrontal, situated at the front of the brain above the eyes, and the parieto-temporal on the side of the brain towards the back. These regions are developed to some extent in the brains of monkeys and apes, but in Man they have expanded so that they form an overwhelming proportion of the brain.

The elaboration of the human brain has been a much slower process than the adaptation of the body. Weidenreich (1939) has shown that in Peking man the structure of the limbs is completely human and implies the perfection of the erect posture. Endocranial casts, however, show that the brain of this type, while much more advanced than that of any ape, was far behind that of modern man in its development. It stands, indeed, almost midway between the apes and modern man (Shellshear and Elliot Smith 1934).

How to define man has been a problem since the beginnings of human speculation. Undoubtedly the most satisfactory definitions are in terms of function rather than structure—it is man's activities which are distinctive. Nevertheless these depend upon certain structural features, and above all upon the development of the brain. Human intelligence seemingly demands a certain minimum size of brain, appreciably greater than is found in any man-like ape, the difference being due to greater development of the association areas. Certain parts of these areas are known to be related to the distinctively human power of articulate speech. Sir Grafton Elliot Smith (1927) and also Shellshear and Elliot Smith (1934) have demonstrated the precocious enlargement of these very regions in endocranial casts from the ancient human skulls of Trinil, Peking, Piltdown and Broken Hill. In size of brain the Trinil and Peking skulls come very close to our estimate of the minimum permissible in man. It may therefore be postulated that a genuinely human type must possess a brain of human size (upwards of 750 ccs.) showing clear evidence of the expansion of the association areas and particularly of those parts associated with the function of speech. Nevertheless, a type which does not fulfil these criteria, but which in posture, and perhaps also dentition, is more human than ape-like, must be considered proto-human. That such types formerly existed is certain in view of Weidenreich's observations on Peking man.

The development of the brain must have been powerfully influenced by the liberation of the hands as instruments for the exploration and control of the environment. These highly adaptable organs not only enabled the potentialities of the expanding brain to be exploited but provided stimuli to further cerebral evolution. To the ancestors of man these developments were of vital importance, for in their new environment the conditions of life were more severe than those faced by their arboreal relatives. Moreover, by animal standards the proto-human type was but feebly equipped for self-protection; it was neither particularly large and powerful in body nor especially fleet of foot, while the differences in the jaws and teeth would render these less efficient as defensive weapons than those of the apes. The collaboration of the liberated hand with the expanding brain, however. permitted a revolutionary change in the biological orientation of the proto-human stock, strikingly depicted by Alsberg (1934):

> Man and the apes develop on diametrically opposed principles; the animal on the principle of physical or organismal adaptation, man on that of extra-physical or non-organismal adaptation, i.e. of the liberation of his body from the necessity of (physical) adaptation, by means of extra-physical means, by 'tools.'

Though the handling, and even to a limited extent the deliberate utilisation of outside objects is seen in monkeys and apes, Alsberg points out that this is " entirely insignificant for their evolution itself "; the ape can exist without these adjuncts. The proto-human type, on the contrary, relied more and more on such instruments, as hand and brain became capable of using them more efficiently. Thus the random use of natural objects was followed by their more careful selection to serve particular ends, and their deliberate improvement the better to fulfil their purpose, the process culminating in the actual manufacture of definite implements.

This process, however, is by no means the only expression of increasing cerebral endowment in the proto-human stock. As Alsberg has remarked: " Alongside of his technical tools, man has also created mental tools; the word, as the basic element of our speech, and the concept, as the basic element of our reason." Articulate speech, even in its most rudimentary form, could greatly increase the possibilities of effective co-operation between one individual and another; increasing mental acuity could express itself in the progressive exercise of deliberate craft and cunning, of foresight and planning. These manifestations of cerebral evolution are interdependent and cannot be divorced from one another. The manufacture of an implement is the concrete expression of foresight and deliberate planning; the implement must be visualised before it is fashioned, and the material chosen and the method of manufacture adapted to achieve the predetermined end. Such processes compel some formulation of mental concepts. Moreover, the technique of achieving such results could hardly be transmitted from one individual to another without the aid of speech to reinforce demonstration; thus concepts must perforce be expressed in words. To possess these powers the brain of the tool-maker must have attained the human level of development. Deliberately fashioned implements may therefore be regarded as the handiwork of a true human being, even though no remains of skulls are available to represent their maker.

The Rise of the Man-like Apes.

The Primates make their first appearance as fossils at the very beginning of the Cenozoic Age or Age of Mammals. Their earlier precursors were probably primitive insectivorous mammals such as have been discovered in Mongolian deposits belonging to the final phase of the Mesozoic Age (the Age of Reptiles). These ancestors of the Primates may well have resembled the Tree Shrews of the East Indies, which we are in doubt whether to regard as insectivores or as Primates. From the ancestors of other mammalian orders those of the Primates were distinguished by their concentration on an arboreal manner of life, which exerted a vital influence upon their structural development. The primitive mammals had relied particularly upon their sense of smell, but this is of less use to a climbing than to a ground-living animal. In arboreal life sight is of more value than smell. Consequently, as Sir Grafton Elliot Smith has emphasised, smell in the Primates has become subsidiary to sight and also to the more delicate sense of touch mediated by the grasping hands and feet. The increasing importance of these senses initiated an expansion of the brain which is characteristic of the Primates.

Fossil remains of Primates from the opening phases of the Age of Mammals, the Palaeocene and Eocene periods, have been found abundantly in Europe and in North America, besides a few fragmentary specimens from China. They have been classified into more than twenty genera and very many species; while some of these are known only from fragments such as jaws and teeth, in other cases almost complete skeletons have been found. These earliest known Primates are already divisible into two groups (Gregory 1922, le Gros Clark 1934), one allied to the modern lemurs, the other to the spectral tarsier, but at this stage no trace of genuine monkeys or apes has been found.

Both in Europe and in North America these early Primates disappeared towards the end of the Eocene period. Those of America, both lemurs and tarsiers, left no descendants, unless the South American monkeys are an offshoot of the latter group. Among the European fossils, however, we find the probable ancestors both of the living Madagascan lemurs and of the spectral tarsier. Further, certain European fossil tarsiers show in their jaws and teeth a distinct approach to the characters of the monkeys and apes, suggesting that these more advanced Primates arose as an offshoot from the tarsier group.

No further stages in this development have been found in Europe. From late Eocene deposits of Burma, however, Dr. G. E. Pilgrim in 1927 described some fragments of jaws and teeth which he considered might possibly belong to a Primate linking the tarsiers with the anthropoid apes. More recently Colbert (1937, 1938) has described a lower jaw from the same deposits which he considers to be definitely that of a Primate. In this animal, named Amphipithecus, the cheek teeth are more similar to those of later fossil anthropoid apes than to any others. There are, however, three premolar teeth as in lemurs and New World monkeys, though the additional tooth is clearly in process of disappearance. In this respect, therefore, Amphipithecus is approaching the condition seen in Old World monkeys, anthropoid apes and man, where the premolar teeth are only two in number. Thus there are good grounds for Colbert's claim that Amphipithecus is closely related to the ancestors of the Old World monkeys and apes.

The earliest undoubted representatives of these Primates belong to the immediately succeeding period, the early Oligocene. Their fossil remains have been found in the Fayum deposits of Egypt, so that these are the oldest known African Primates. No Primate remains of this epoch are as yet known from any other part of the world. Those from Egypt, which have been extensively discussed by Gregory (1922) and other authorities, belong to several diverse types. In the most generalised, Parapithecus, represented by a lower jaw not much larger than that of a living marmoset, the number of teeth is the same as in Old World monkeys and anthropoid apes, while their form, like that of the whole jaw, is intermediate between those of the tarsiers and of the more advanced Primates. Parapithecus thus suggests a type which might well have given rise to both Old World monkeys and anthropoid apes; this however was contemporary with others more definitely specialised. The fragmentary lower jaw of an animal named Apidium seems to present in an incipient stage the tooth characters of the Old World monkeys. Another more complete lower jaw represents an animal to which the unwieldy name of Propliopithecus has been given. This Primate was considerably larger than Parapithecus, equalling in size one of the smaller African monkeys of the present day. In the form of its cheek teeth it stands midway between Parapithecus and the undoubted anthropoid apes of later times. Although Propliopithecus shows more primitive features than any later anthropoid ape, for instance in the small size of its canine teeth, it is generally regarded as already belonging to this group. As might be expected it approaches most nearly to the small gibbons, but it could equally well have given rise to the large apes which make their first appearance in deposits of the succeeding Miocene period.

These Oligocene Primates of Egypt were contemporary with a remarkable array of other mammalian types. Some of these have no relatives in Eocene and Oligocene deposits outside Africa, so that their previous evolution must have taken place on this continent. This ancient African fauna includes a variety of forms, some of great size, allied to the living dassies (Hyracoidea), as well as the ancestors of the elephants and of the sea-cows (Sirenia). Mingled with the African types, however, are carnivores and hoofed animals which were immigrants from the north, their ancestors being found in earlier deposits of Europe and Asia. So long as no definite precursors of the Fayum Primates were known in Europe or Asia, it appeared most likely that these animals also had evolved in Africa, probably from some early offshoot of the tarsier group. While this is still possible, the discovery of a more primitive but seemingly nearly allied type, Amphipithecus, in late Eocene deposits of Burma weights the scales in favour of the view that these Primates are immigrants from the north or east.

From the later part of the Oligocene period no Primate fossils are yet known. Presumably the Primates of this time were limited in their distribution, not extending into any part of the world where fossils of this age have been discovered. In the succeeding Miocene and Pliocene periods, however, both tailed monkeys and anthropoid apes became widely distributed over the Old World. The evolution of the monkeys unfortunately cannot be traced within the limits of this address, though most interesting fossil representatives of this group have been found in South as well as in North and East Africa; these South African discoveries have recently been reviewed by Dr. R. Broom (1940).

That fossil anthropoid apes occurred in late Miocene and early Pliocene deposits of Europe was already known in the time of Darwin. In later years these remains have been most extensively discussed by Gregory (1922, etc.). One of these apes, Pliopithecus, is a small form closely allied if not ancestral to the living gibbons; its descent from the Oligocene Propliopithecus is suggested by the name chosen for that type. Most of the larger apes of these deposits are assigned to the genus Dryopithecus (the "tree-ape"). They are known to us principally from portions of jaws and isolated teeth, together with a few bones of the limbs, an arm-bone (humerus) and a thighbone. The teeth of these apes can easily be derived from those of Propliopithecus, while teeth, jaws and limb bones could all have given rise equally to those of the modern large apes and of man. In size these animals approached the chimpanzee, but the arm-bone is not as long as in that ape; the possessor of the thigh-bone was capable of standing erect at least as well as any living ape. These large fossil apes of Europe thus possessed a relatively generalised structure, from which it is possible to derive that of man as well as of the living apes. There is, however, no evidence in Europe of forms making a closer approach to human characters. Further, the man-like apes seem to have disappeared from Europe during the Pliocene period, for no undoubted remains of them have been found in late Pliocene or in Pleistocene deposits.

In Asia fossil man-like apes appear at about the same time as in Europe, in the Siwalik deposits of northern India, which belong to the later part of the Miocene and to the Pliocene period. Wadia and Aiyengar (1938) consider that these apes are descended from the Oligocene Primates of Egypt, and that they migrated into India during the Miocene from Europe or North Africa. Like those of Europe, they are known from "pieces of jawbones carrying moieties of dentition, isolated teeth, and a few bones." Of portions of jaws and teeth Wadia and Aiyengar enumerate some sixty; except for one tooth attributed to a gibbon (Hylopithecus), all these belong to large apes. These dismembered remains have been described under a bewildering array of names; however, recent studies (Lewis 1937; Gregory, Hellman and Lewis 1938) have effected a drastic but salutary reduction, from seven genera and nineteen species to four genera and ten species.

Most of these large Indian apes are now included under the name Sivapithecus. This was first applied by Dr. Pilgrim to an ape which he at one time (1915) considered to be possibly the direct ancestor of man, a view which was not generally accepted. Later (1927) Dr. Pilgrim considerably modified his views in the light of further evidence, regarding Sivapithecus as sufficiently primitive to have been ancestral to all the large modern apes and possibly also to Man. Gregory and his co-workers now assign to Sivapithecus a number of apes formerly included in Dryopithecus and other genera. Some of these had been considered to be closely related to the living African apes; the latest studies however, suggest their much nearer kinship to the orang-utan. While most of these apes resembled the chimpanzee in size, one at least possessed teeth as large as those of the gorilla. Other man-like apes from these deposits, Bramapithecus and Sugrivapithecus (Lewis 1934, 1937), were of moderate size, less than the chimpanzee in bulk, and their jaws appear to have been less projecting than in Sivapithecus or Dryopithecus. In Sugrivapithecus, moreover, the canine tooth is smaller than in these other fossil types or in the modern apes. This and some other features have led to the suggestion that Sugrivapithecus may be related to the ancestors of Man.

During the Pliocene period the anthropoid apes gradually disappear from the Siwalik deposits. One of the last survivors, Ramapithecus, possessed an upper jaw with such distinctive features that its first describer, G. E. Lewis (1934), was tempted to consider it as nearly related to Man as to the apes. The most conspicuous of these features are the diminutive size of the incisor and canine teeth, with the consequent narrowing of the front of the palate and rounding of the dental arch. In these respects Ramapithecus makes a definite approach to human characters, but in others it is clearly distinguished from man, as in certain features of the teeth which show that these were used for biting rather than for grinding.

Of the Indian fossils Sugrivapithecus and Ramapithecus undoubtedly make the nearest approach to man. Both of them, however, fall considerably short of humanity in respect of their teeth, which are the only criterion by which their status can be judged, for we have no remains which can even remotely indicate the character of their brain. If it could be established that either of these types was terrestrial rather than arboreal, the arguments for their proto-human status would be powerfully reinforced. Unfortunately there is as yet no direct evidence bearing upon this question. Moreover these remains vary considerably in age. While Sugrivapithecus may date back to the Miocene, Ramapithecus is possibly late Pliocene or even Pleistocene.

The living Asiatic man-like apes reached their present homes in South-eastern Asia and the East Indian islands during late Pliocene or early Pleistocene times. The modern orang-utan is probably descended from Sivapithecus, and its presence in the latest Siwalik deposits has been asserted. This ape also occurs in late Pliocene or early Pleistocene deposits of southern China (v. Koenigswald 1935), where it is accompanied both by a modern gibbon and by an ape, aptly named Gigantopithecus, whose teeth exceed in size even those of the gorilla. Gigantopithecus is probably near of kin to the orang-utan. Nevertheless its teeth display certain resemblances to those of Man, which have led to speculations as to the possible relationship of this type to the ancestors of Man.

Both the European fossil Dryopithecus and the Indian Sivapithecus display resemblances to the living African man-like apes. These have frequently been interpreted in the past as indicating the descent of the African apes from these extra-African forms. Thus it has been implicitly or explicitly assumed that the apes now living in Africa migrated from the northern hemisphere in comparatively recent times. This opinion was maintained, not only after the discovery of the Oligocene Primates of the Fayum, but even after the later identification of anthropoid apes also in Miocene deposits of Egypt. These later Egyptian fossils include both a gibbon, Prohylobates, and a larger ape, resembling Dryopithecus. From these discoveries it was evident that the anthropoid apes had remained established in the region where their earlier ancestors had existed. Despite this, the possibility that man-like apes might at this period have penetrated more deeply into Africa was ignored or even denied (Black 1925).

The falsity of such views was demonstrated when, in 1933, Dr. A. T. Hopwood described jaws and teeth of several anthropoid apes from deposits on the eastern shores of Lake Victoria. These are assigned to the middle or even the earlier part of the Miocene period, showing that the penetration of the apes into central Africa took place at least as early as their migration into Europe and Asia. One of these East African apes, Limnopithecus, belongs to the gibbon group. Another, Proconsul, is a larger ape which in Hopwood's opinion is probably the direct ancestor of the chimpanzee. This interpretation, if established, would suggest that the evolution of the existing African apes from the stage represented by the Fayum Oligocene forms must have taken place wholly on the African continent. Further, if Proconsul were really so intimately related to the chimpanzee, this ape stock had surely already separated from that of man. If it is to the African apes that man is most nearly related, it would seem then that his divergence from them must also have taken place in Africa. This last inference, it must be pointed out, is not accepted by Hopwood, who believes that man arose from an Asiatic Primate type.

Gregory and his co-workers (1938, 1939) interpret the remains of Proconsul rather differently from Hopwood. In their opinion this type is "near to the stem of the entire ape-man stock," being probably the most ancient, and certainly in dental characters the most primitive, of the large anthropoid apes. Even if this view is correct, it is more likely that the living African apes are descended from an African fossil type like Proconsul than from some later immigrant from the north. This ape, indeed, may well come very close to the common ancestral type of the gorilla, chimpanzee and man, whose existence Sir Arthur Keith has anticipated.

Some further remains of Miocene anthropoid apes have been discovered in Kenya by Dr. L. S. B. Leakey. As yet this is the only region in central Africa, in which fossil apes have been found. We may, however, reasonably hope for the discovery in Kenya or further west of remains which will demonstrate the connection between the Miocene and the living man-like apes of Africa.*

PROTO-HUMAN TYPES IN SOUTH AFRICA.

In southern Africa no fossil remains of ordinary man-like apes have as yet been discovered. From the limestone deposits of Bechuanaland and the Transvaal, however, have come a group of remarkable fossil types, which present strong claims to be considered proto-human. The first, and for some ten years the only, representative of this group was the Taungs skull, described by Professor R. A. Dart in 1925 under the name Australopithecus. A recapitulation of the divergent views expressed upon this fossil is unnecessary here since Professor Dart himself has provided this in a recent paper (1940). From 1936 onwards our knowledge has been greatly extended by the discoveries of Dr. Broom at Sterkfontein and Kromdraai, which have revealed two further members of this group, Plesianthropus and Paranthropus. These discoveries, described from time to time in various papers by Dr. Broom, have also been illuminated by the studies of Professor W. K. Gregory and Dr. Milo Hellman (1939, 1940). Moreover, Dr. Broom has been most generous in permitting me and my fellow-workers in Professor Dart's department to examine the Sterkfontein and Kromdraai remains in comparison with those from Taungs.

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* Lönnberg (*Ark. Zool, 29*, 1-23, 1937) has described a fragment from the later Pleistocene of Kenya which he believes to belong to a chimpanzee-like ape.

Compared with the remains of fossil man-like apes from other parts of the world, these South African fossils are exceptionally well preserved. They comprise not only jaws and teeth, but portions of the skull including natural casts of its interior, as well as some remains of other parts of the skeleton; in the case of Plesianthropus the remains represent several individuals. While each of the three types has its own peculiar features, they are united by an assemblage of characters of fundamental importance. It is evident from their geological environment that all three were inhabitants of open, unforested country. They were therefore ground-living forms, and in all of them there are features indicating that the poise of the head was nearer to that of man than in the living apes. This would indicate that these creatures were more perfectly erect than the modern large apes, so that their hands cannot have been used for support.

In all three types the face is less projecting than in the living apes. This is due very largely to differences in the teeth, essentially the same in the Taungs skull, which shows the milk dentition, and those from Sterkfontein and Kromdraai in which the permanent teeth are present. The incisor teeth are smaller and less projecting than in the apes; the canines are even more strikingly diminutive, and unlike those of the apes their tips do not interlock with one another. This difference is emphasised by the form of the premolar teeth, which in apes bear sharp edges forming with the canines a pair of jagged shears, but in Plesianthropus and Paranthropus have flattened circular crowns almost like those of man. Implicit in this contrast is that between the biting habits of the apes and chewing in the human fashion; that the teeth of these creatures were employed for chewing is indicated also by the manner in which their crowns have become worn (Gregory and Hellman 1940). A further consequence of the small size of the front teeth in these fossil types is the narrowing and rounding of the front of the dental arch. The crowns of the molar teeth resemble those of man more closely than do those of either living or fossil apes. Their difference from those of such primitive human types as Peking man is as much in their greater size as in their structure, which i intermediate between that of man and of the fossil apes

Dryopithecus and Sivapithecus. Thus in their jaws the teeth, wherein these South African types can be compared with other fossils as well as with living apes, they consistently display a much closer resemblance to man than is seen in any other type.

Weidenreich (1939) on the basis of his monumental studies on the teeth of Peking man, believes that the ancestors of man never possessed the large canine teeth seen in all the large apes, living and fossil. He therefore supposes that they diverged from the stock of the man-like apes at an earlier stage when the canine teeth were still small as in Propliopithecus. These South African fossils with their small canines must in that case be members of this proto-human group. On the other hand Gregory and Hellman, while equally convinced of the proto-human character of these fossils, conclude from their resemblances to Dryopithecus and Sivapithecus that they are descended from Dryopithecus-like ancestors. They believe moreover that the small canine teeth of these fossil types and of man have been attained by reduction from larger canines such as are found in Sivapithecus, a reduction whose initial stages are suggested in Ramapithecus and Sugrivapithecus.

To aid us further in determining the status of these creatures we have a source of information not available in the case of any fossil type previously discussed, the form of the brain. In both Australopithecus and Plesianthropus this is revealed by natural casts of the interior of the skull; in Paranthropus also a part of the cavity of the brain-case is preserved, which suggests that the brain of this type was larger than that of the gorilla.

The brains of the other South African fossils, while larger than that of the chimpanzee, probably did not exceed that of the gorilla, but so far as we can judge neither of these types equalled the gorilla in bulk of body. However, the brain casts of these fossils differ strikingly in form from those of the living apes, owing to the greater development of portions of both association areas. The expansion of the prefrontal region has taken place in its lower portion, immediately above the eye. This, as emphasised by Sir Grafton Elliot Smith (1927), has given the frontal lobe of the brain a contour much nearer to that of Man than to that of the living apes. A further consequence of this has been the raising up and rounding of the forehead and the diminution of the bony shelf above the eyes. The greater expansion of the parietal region in the fossil casts as compared with those of modern apes is evidenced by its bolder convexity.

Study of the details of brain structure revealed by the fossil casts adds weight to the conclusions drawn from their gross form. Professor Dart's interpretation of these features in Australopithecus has been questioned by anatomists who, not having the original cast before them, have not appreciated the clarity with which such details are displayed in it. It is extremely satisfactory that an equally fine cast, revealing closely similar features, forms part of the remains of Plesianthropus. Thus in the form of the brain as in their other features these fossil types show more resemblance to man than does any living ape.

It has been suggested more than once that these fossils represent merely an offshoot of the African ape stock which contrived to acquire spuriously human-like characters. Such an interpretation, however, appears far-fetched when we consider how practically every feature in which these fossil types differ from the apes represents an approach to the human condition. An ape that could mimic so closely the peculiar features of man must have been intimately related to him.

These types however are not yet truly human. Their brains are still below the human level in size. Moreover, Professor Dart has pointed out that the brain of Australopithecus shows no evidence of the expansion of that part of the temporal region, adjacent to the area concerned with hearing, which is intimately associated with the power of articulate speech, and which is conspicuously developed in the brains of even primitive human beings. In Plesianthropus the lack of this expansion is equally evident. As Professor Dart declared in his first account of Australopithecus: "A creature with anthropoid brain capacity, and lacking the distinctive, localised temporal expansions which appear to be concomitant with and necessary to articulate man, is no true man." It seems necessary, therefore, as Professor Dart has suggested, to place these fossils in a distinct group of the Primates, intermediate between the anthropoid apes and man; we may fairly call them proto-human.

Nevertheless these types cannot be the actual ancestors of man. Plesianthropus and Paranthropus, indeed, are not older than middle Pleistocene; they belong therefore to a time when true human beings, manufacturing implements of a complex type, already inhabited southern Africa. A possible relic of such a human contemporary of Plesianthropus is the tooth from Sterkfontein described by Professor J. C. M. Shaw (1940). Australopithecus is certainly more ancient, belonging to the early Pleistocene if not to the Pliocene. It may therefore have inhabited South Africa before any true human beings appeared here, but it is not ancient enough to be the parent of the human types which became widely spread over the earth's surface during early Pleistocene times.

It seems therefore that these types had lagged behind on the road of human evolution, failing to acquire the latest and most significantly human features of the brain. With this may be associated the fact that, while both Professor Dart (1934) and Dr. Broom (1934) have inferred that Australopithecus probably made use of tools of a sort, no trace of any fabricated implement has been found in association with these fossils. Australopithecus probably indicates fairly accurately the character of the ground-living ancestors of man before the culminating developments in the brain took place. It belongs, however, to a more conservative branch of the proto-human stock. That branch was endowed with considerable vitality, surviving to give rise to Plesianthropus and Paranthropus, who existed alongside of human types from which they must have differed as much as a Bushman from a European.

It is possible that fossils still older and nearer to the true ancestral type of man will yet be found in southern Africa. These proto-human types may, however, have wandered southwards from a home further to the north. Possibly they are related to the Indian fossils Ramapithecus and Sugrivapithecus. Hrdlicka (1935) considered Ramapithecus nearer to man than Australopithecus, but such a view is untenable in face of the evidence furnished by Plesianthropus and Paranthropus. Lewis (1937) is more probably correct in considering Ramapithecus as intermediate between the unspecialised Miocene apes on the one hand and Australopithecus and man on the other. This does not mean, however, that Australopithecus and its relatives had wandered from India to South Africa. If these widely dispersed types are really related, it seems probable that they spread outwards from some intermediate region such as north-east Africa. The ground-living proto-human type may therefore have originated and developed not far from the original home of the man-like apes.

In this connection it is remarkable to observe that Professor C. van Riet Lowe has found in Uganda implements more primitive in character, and apparently more ancient, than any which have been discovered in South Africa. These he has been able to trace back through a very long period of time, probably extending out of the early Pleistocene into the Pliocene. The series ends at last in examples which seem to mark the very first attempt at the deliberate fashioning of implements. If we are justified in the belief that this art involves, not only human hands, but a brain of human calibre and some rudimentary form of speech, it would seem that here we are coming close to the scene of the very beginnings of man.

CONCLUSION.

The development of Man thus appears as a succession of steps, each possible only because of those which preceded it. To the arboreal habits of the primitive Primates we owe the initial expansion of the brain stimulated by accentuated dependence on vision and on the tactile functions of the flexible grasping hand; these qualities, however, form part of the heritage of all monkeys and apes. The distinctive climbing habits of the man-like apes laid the foundations of the erect posture, but the full benefit of this posture was reaped by man only when he returned from the trees to the ground. On the ground, the erect posture resulted in the liberation of the hands from the function of support, so that they could become the organs of expression of a developing brain and a stimulus to its further progress. This progress, however, was not inevitable; the South African proto-human types failed to attain completely human status because of the halt in the process of expansion of their brain, and especially of their lack of the developments associated with articulate speech and with craftsmanship. Only by successfully traversing this complicated pathway, beset maze-like by evolutionary blind alleys, did man attain his full development.

We have found evidence which encourages us to believe that the crucial steps in this development took place on the African continent. This continent was the original and abiding home of the man-like apes, and it is very probable that on it there occurred both the descent of the proto-human type from the trees and the subsequent expansion of the brain with all of its consequences. That these events took place actually in southern Africa does not appear likely; rather it seems that north and east Africa, which have already furnished such important evidence, will reveal the vital stages in man's history. Nevertheless the fact that southern Africa has given us the only fossils which throw light upon the state of man after his descent from the trees but before the full development of his brain, may lead us to expect that notable discoveries still await us in the south.

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STAGES IN THE PROCESS OF RIVER-SUPERIMPOSITION IN THE SOUTHERN TRANSVAAL,

BY

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Read July, 1940.

The river systems of Southern Africa appear to be so closely conditioned by the process of drainage-superimposition that it is rather surprising to find no systematic account of the process in our South African geographical and geological literature. Fortunately there are areas in this country where the process is still in progress and where stages in the development of such drainage systems can still be observed. Almost anywhere near the margins of the Karroo System the results of superimposition are observable though it is often difficult to distinguish these results from the effects of other processes which are going on simultaneously. In the Southern Transvaal superimposition is very evidently taking place and the process can be distinguished from other types of river development fairly clearly. The object of these short notes is to elucidate some of the stages in the process which may be observed in this region where the Karroo System is gradually being stripped off the underlying pre-Karroo surface of the Waterberg, Transvaal and Witwatersrand Systems (Fig. 1).

THE "IMPOSING" FORMATION AND THE "RECEPTIVE" SURFACE.

Over the whole of this northern marginal area the character of the overlying Karroo beds is fairly homogeneous. At the base, lying unconformably on the older surfaces, is the Dwyka Tillite having the general character of ground moraine. Its thickness has not been accurately determined over most of the area, but it probably varies from about 50 feet in some parts of the Witwatersrand(¹) to about 90 feet

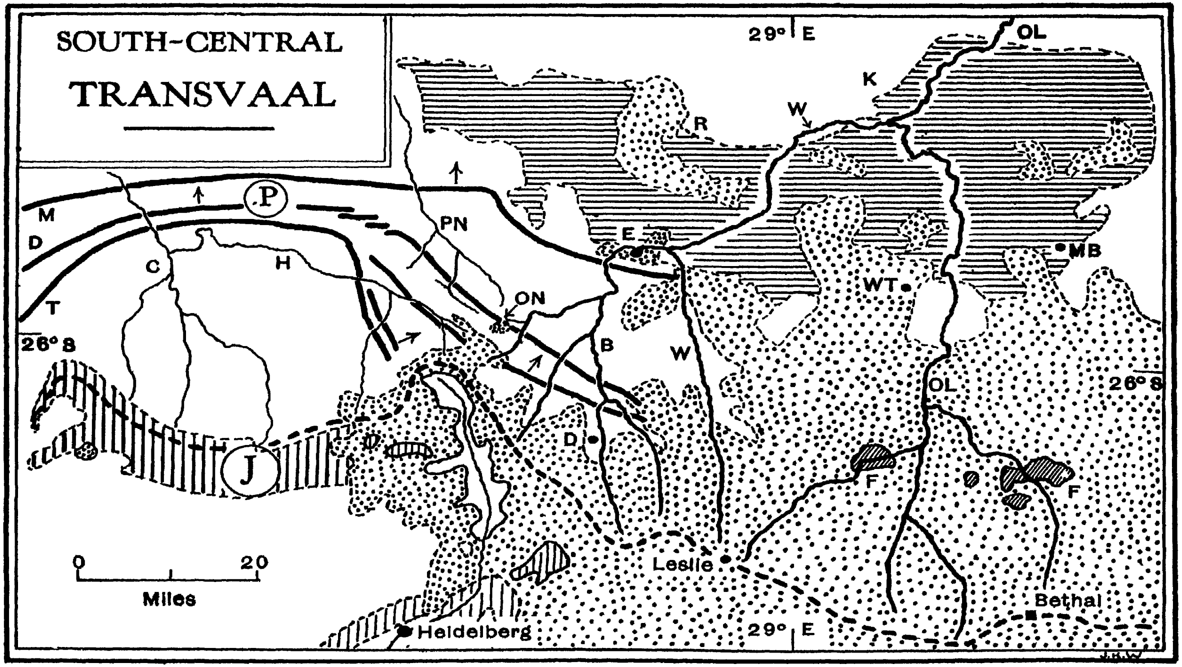

Fig. 1.—*The area described in the paper.* Horizontal Shading—Waterberg Surface; Vertical Shading—Witwatersrand Surface; Diagonal Shading—Felsite; Stippled—Karroo Surface. The heavy broken line shows the position of the main watershed. M—Magaliesberg quartzite; D—Daspoort quartzite; T—Timeball Hill quartzite; C—Crocodile River; H—Hennops River; PN—Pienaars River; ON—Onbekend; E—Erasmus; B—The Bronkhorst Spruit; W—Wilge River; RK—Rhenoster Kop Escarpment; OL—Olifants River; D—Delmas; F—Felsite; P—Pretoria; J—Johannesburg.

in parts of the Bethal-Middelburg area(²). In some parts of the area Dwyka sandstone and shale have also been found associated with the tillite, but these beds are rather easily eroded and often the only evidence of the presence of the tillite is the abundance of glacial boulders and pebbles on the denuded pre-Karroo surface.

Above the Dwyka lie the Ecca beds, consisting of grits, sandstones and shales together with seams of coal of varying thickness. Venter (2) gives the following section (grouping together several of the thinner beds) in the neighbourhood of the watershed on the farm Gruisfontein, 48, about 5 miles S.W. of Leslie:

Dolerite	179 feet
Sandstone, with thin shale	20
Shales and shaly sandstone	96
Dolerite and thin sandstone	149
Sandstone, shales and thin coal seams ...	289
Dolerite	7
Sandstone	41
Coal, shale and thin sandstone	24
Sandstone	40
Shale, sandstone and coal	26
Dwyka Tillite	92

The thicknesses of the sandstones and shales are fairly typical of the Ecca beds of the area, but here on the watershed the dolerite sheets are very strongly developed, whereas they are often absent or only weakly represented near the margins of the Karroo system where the actual process of stream imposition takes place. Where the Karroo streams start to cut into the pre-Karroo surface the valleys in the Karroo beds vary in depth from as little as 20 feet to as much as 300 feet, so that only the lowest third of the succession shown above is generally involved in the actual transference of drainage to the older surface.

The character of the pre-Karroo surface which "receives" the drainage from the Karroo beds is of much greater diversity than the Karroo formation and is better considered, perhaps, as conditioning the extent to which imposition is possible. The different types of pre-Karroo surface will therefore be described in connection with the superimposing process in different parts of the area.

Note: The small numbers in brackets, e.g. ($_1$) etc. refer to the items in the bibliography on page 96.

PRE-DENUDATION COURSES.

Owing to the fact that the Karroo System is not folded in this region but is almost horizontal, the valley topography on the Karroo surface is comparatively simple. The main watershed is the site of outcrops of dolerite sheets (2, Map) which, however, are deeply weathered and disintegrated, forming a black, clayey soil. Few exposures of the fresh rock are seen in the area but the sheets form the divide between the northward-sloping surface, with its average gradient of about 9 feet per mile, and the steeper slope towards the Vaal River to the south, with which we are not immediately concerned.

The northward-flowing streams are the headwaters of the Olifants River and of its tributary, the Wilge River The courses of these streams on the Karroo beds are of an unexceptional type. Near the watershed the surface is rolling country, with rounded ridges and wide, open valleys which are cut, in places, as much as two or three hundred feet below the "bults." As distance from the watershed increases the general surface of the country becomes more even but the stream-courses are cut more deeply into the surface, the local character of the valley being determined, of course, by the local outcrops. Thus in shale outcrops the valley is generally shallow and wide; in the harder sandstone outcrops it is generally deeper and narrower and, in places, there are rapids or small waterfalls where streams leave the sandstone or dolerite.

Towards the margin of the Karroo surface the gradient is lower and the stream courses are naturally less deeply cut. The valleys are, in general, wide, open features and in many places the drainage becomes indecisive, so that pans cover considerable areas. These pans are also seen, in many places, on the flatter portions of the underlying pre-Karroo surface, on which they appear to have been imposed from the Karroo surface. Thus, with the exception of the horizontal sandstones and the occasional sills of dolerite, there is nothing in the Karroo drainage systems to provide nodal points in the stream courses or to form "poorts" or gaps in transverse ridges. The stream patterns are of the simple dendritic or sub-dendritic type, with little evidence of strong control by geological structure.

DENUDATIONAL IMPOSITION.

Where the streams pass from the Karroo surface to the pre-Karroo, the character of their courses undergoes a definite, and often a sudden, change. To appreciate the nature of this change the character of the pre-Karroo surfaces in this region must first be considered.

Three types of pre-Karroo surface are mainly involved in the process: the Waterberg System, with its associated Rooiberg lavas; the Pretoria Series of the Transvaal System, with which is associated the Dolomite and Black Reef Series; and, thirdly, the Witwatersrand System with the associated Ventersdorp diabase (Fig. 1).

The Waterberg Surface lies immediately to the north of the Karroo surface and is formed mainly of sandstones and grits, which pass through quartzitic sandstones to quartzites. The beds are inclined at angles of about 5° to 12° forming a broad syncline with a W-E trending axis, but the northern edge has been subjected to strong faulting and overthrusting so that near the confluence of the Olifants and its tributary the Wilge, the beds are vertical ([3]). Taking the Waterberg surface as a whole we may regard it as a part of the pre-Karroo peneplain formed by the Carboniferous ice-sheet. Its surface is predominantly flat and even, and gives the impression of merging without break into the Karroo surface to the south of it. Moreover the Waterberg surface is partially covered with still-remaining patches of Ecca and Dwyka beds and some of the smaller tributary streams still take their rise on these outliers of the Karroo System.

The process of superimposition is thus in this area only partially complete: the main streams have cut through the lowest layers of the Karroo System but the smaller streams are still in the process of passing from Karroo to pre-Karroo surface.

In the Olifants and the Wilge valleys the resulting effects are much the same. In both cases the rivers pass from a relatively open valley in the Karroo beds to a steep-sided, gorge-like course in the Waterberg formation, the gorge-like character becoming more and more strongly developed with increasing distance from the Karroo surface.

Thus towards the northern margin of the Waterberg surface the Olifants River flows in a gorge more than a thousand feet deep and its course appears to be but slightly related to the structural changes of character of the Waterberg formation. The Wilge River also cuts a similar deep gorge in the Waterberg formation and when it reaches the Rhenoster Kop Escarpment—the northern edge of the Waterberg plateau in this area—an apparently anomalous condition occurs. The river issues from its gorge on to open granite country, lying about 1,500 feet below the Waterberg surface. For about ten miles it flows over the granite and parallel to the Rhenoster Kop Escarpment and then it re-enters the Waterberg Plateau, and joins the Olifants within the plateau area (Fig. 2). The occurrence of this surprising re-entrance into a plateau which it had already left is scarcely explicable on any other basis except that of superimposition. From the Karroo surface the river has clearly been imposed on the outcrops of quartzite, granite, soft sandstone and felsite in an entirely discordant manner. The open valley in the granite is due to the more rapid erosion of that rock, and the re-entry into the plateau has been inherited from the time when the river's course acquired its direction on the Karroo surface.

THE SURFACE OF THE TRANSVAAL SYSTEM.

The second type of surface upon which superimposition is now taking place is that of the Pretoria Series of the Transvaal System, together with the Dolomite series of the same system. This surface is more complex than the Waterberg because it is made up of alternating hard and soft beds: the Magaliesberg, Daspoort and Timeball Hill quartzites and the intervening shales, reinforced, however, by intercalated dolerite. This surface, exposed and eroded gives, of course, the Bankenveld topography, which has been described both structurally and topographically(⁴). This pre-Karroo surface has been subjected to peneplanation by the Carboniferous ice-sheet and near the margin of the Karroo beds the smoothed surface formed by these quartzites and shales bears witness to the effective planing action of the ice(⁵). About 20 miles to the S.E of Pretoria such glaciated topography is well shown in the neighbourhood of Onbekend ("ON" in Fig. 1), but the even surface becomes less and less even with increasing distance from the Karroo covering, as recent erosion has excavated the softer beds, leaving the harder quartzites as prominent ridges.

In spite of this recent erosion the differing degrees of effectiveness in the ice erosion can still be distinguished. Thus, between the S.E.-trending ridges to the S.E. of Pretoria the valley between the Daspoort and Black Reef quartzites

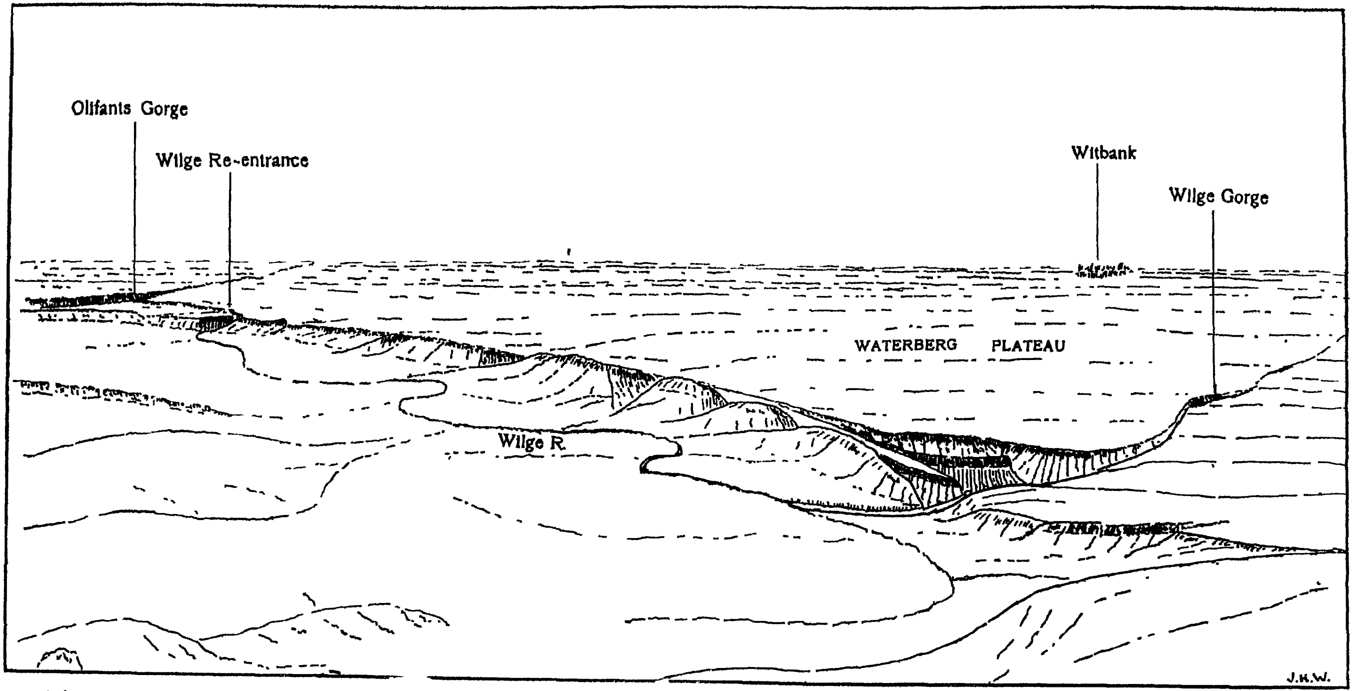

Fig. 2.—The Rhenoster Kop Escarpment and the Waterberg Plateau from Rhenoster Kop looking S.E. The Wilge River issues from the gorge on the right, flows nine miles through the open granite country in the foreground and re-enters the plateau to join the Olifants on the left of the sketch.

was hollowed out to a depth of 350 feet. In the broader valley between the Magaliesberg and Daspoort quartzites the ice erosion was effective to a depth of 500 feet. It is natural that the excavation by the ice in these valleys trending in the same direction as the ice moved, should be greater than in the soft beds between the quartzites lying athwart the movement of the ice-sheet, where the valley watersheds show a slighter glacial excavation.

The pre-Karroo surface, before post-Karroo stream erosion becomes effective, thus takes the form of the three quartzites (the Timeball Hill bed duplicated in places) forming subdued ridges with valleys of varying depth between them (Fig. 3) Here, therefore, the process of superimposition is likely to show features somewhat different from those on the Waterberg plateau.

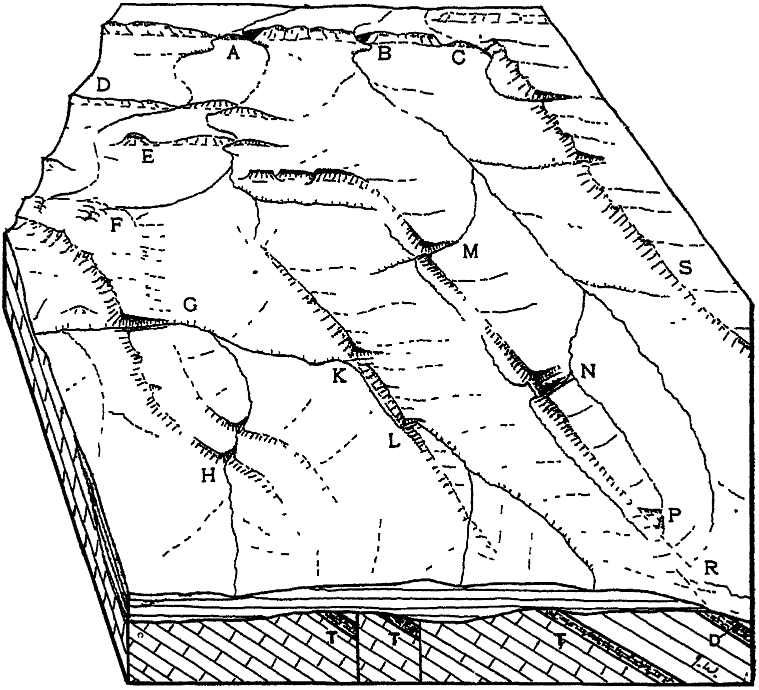

Fig. 3. Ridges of Pretoria Quartzites to the S.E. of Pretoria.

A—Derdepoort; B—Baviaanspoort; C—Franspoort; D—Meintjes Kop Ridge; E—Struben's Kop; F—Garstfontein; G—Rietvleipoort; H—The Witkoppies Spruit; K—Grootfontein Spruit; M—Zwavelspoort; N—Tiegerpoort; P—Klipkop; R—Onbekend; S—Magaliesberg; T—Timeball Hill Quartzite; D^1—Daspoort Quartzite.

CLEAR CASES OF TRANSVERSE SUPERIMPOSED COURSES.

One can see the process most clearly in this area near the margin of the Karroo beds between Onbekend and the area just north of Delmas ("D" in Fig. 1), where the Timeball Hill and Daspoort ridges are now being denuded of their Karroo covering. Here the process is a very simple one. At the extreme margin of the Karroo surface the headwaters of the Bronkhorst Spruit have passed on to the surface of the Pretoria series and are just beginning to cut their poorts in the recently denuded quartzites. At present these gaps are rather shallow features, not more than about 150 feet deep and the ridges are beginning to become prominent as the softer beds are excavated by stream erosion. Whatever may be the case elsewhere on the surface of the Pretoria Series, here, at least, the process of superimposition is producing a transverse drainage system with poorts or gaps in the hard beds, and, between the hard beds, the original pre-Karroo surface is most nearly preserved in the secondary watersheds between the lateral tributaries of the major streams. Lower down the course of the Bronkhorst Spruit, near Erasmus ("E" in Fig. 1), the same very clear imposition of the stream on the recently denuded Magaliesberg quartzite produces a poort, as yet shallow, but obviously of the same type as the more spectacular poorts near Pretoria.

Following the Pretoria quartzites to the north and north-west of Onbekend we have receded from the zone of immediate contact between Karroo and pre-Karroo surface and the task of distinguishing imposed streams from others becomes more difficult and uncertain, because since the denudation of the pre-Karroo surface enough time has elapsed for the development of secondary stream courses which are directly related to the exposed pre-Karroo topography. One may say that the problem of differentiating Karroo-imposed courses from post-Karroo courses increases in difficulty and uncertainty with increasing distance from the existing Karroo surface Any attempt at understanding the origin and evolution of the drainage further west must therefore begin with the streams in the immediate vicinity of the present Karroo margin.

The two major streams which are most clearly superimposed on the pre-Karroo surface and which appear to have been little affected by post-Karroo developments are the upper courses of the Hennops River (Six Mile Spruit) and the Pienaars River ("H" and "PN" in Fig. 1).

In the upper course of the Hennops River, as we have already seen, the Timeball Hill quartzite near Olifantsfontein, on the Germiston-Pretoria railway, stands as a double-faulted ridge about 350 feet above the ice-eroded valley in the dolomite. The interesting phenomenon connected with this double ridge is that the western headwater of the Hennops River—we may call this headwater the Witkoppies Spruit (Fig. 3, "H")—has a course which appears to be quite independent of this pre-Karroo topography. The stream cuts obliquely across both the ridges and then, after joining the Grootfontein Spruit, cuts transversely through them again(6)

The two poorts formed by the first oblique cut, on the farms Elandsfontein 452 and Witkoppies 105, are more than 300 feet deep and without any doubt have been formed by the imposition of the stream on the quartzite.

Further up the course of the Witkoppies Spruit another example of superimposition is so near to the Karroo surface that the process here is also beyond doubt. Two or three miles NE of Birchleigh Station, on Witfontein 45, a headwater of the Witkoppies Spruit has begun to excavate a poort in the Black Reef and Orange Grove quartzites, which here overlap. At the present time the poort has been cut to a depth of about 120 feet in the Orange Grove Quartzite and the feature provides a perfect example of the initial stages of an excavated ridge and poort. The gradual removal of the granite on the upper side of the quartzites and of the dolomite below them, will, in time, leave the quartzites standing as a prominent ridge with a characteristic deeply-cut poort.

On the easterly headwater of the Hennops River, which we may call the Grootfontein Spruit ("GKL" in Fig. 3), there is another very clear example of a stream course bearing no direct relationship to the structure of its basin. The headstream rising on Bronkhorstfontein 177 (shown in the geological map) which flows past Bapsfontein store and post office, cuts obliquely across the eastern ridge formed by the Timeball Hill quartzite and then, three or four miles lower in its course, cuts back across the same ridge, on the farm Grootfontein 220. This double cut is, however, more striking than the map indicate, for, on Grootfontein 220 the quartzite is deeply hollowed by another gap of pre-Karroo age, in the floor of which the Dwyka tillite is still found ("K" in Fig. 3). This wide, pre-Karroo gap is less than a mile from the narrow, freshly-cut gap occupied by the Grootfontein Spruit. There could scarcely be a clearer example of the complete disregard of the older surface-features by a superimposed stream.

SUPERIMPOSITION AND HEADWARD EROSION.

One of the major difficulties in the field is to distinguish between neks or poorts which have been formed by superimposition and those which are due to headward erosion. The distinction becomes all the more difficult near the margin of the superimposing formation where superimposed streams and streams developing on the older, denuded surface are found in the same river system; for it is clear that as soon as a superimposed stream has established itself on the older surface new tributary streams will develop on the older surface and will be related only to that surface. In this connection the presence of faults in the older formation has an important significance. The question arises whether a stream along a fault-plane in the older formation is likely to be a superimposed stream or not. The question might perhaps with advantage be put in the opposite way: Do streams flowing on the newer formation adapt themselves to fault-planes near their courses in the older surface? The evidence of the two streams we have just considered (the Witkoppies and Grootfontein Spruits) gives a decidedly negative answer to that question so far as the early stages of imposition are concerned. The fault on Witkoppies 105 is not used by the Witkoppies Spruit in its course through the quartzite and, as we have seen, the Grootfontein pre-Karroo gap is ignored by the Grootfontein Spruit. This, after all, is what we should expect in superimposition, but it is not always easy to find clear demonstrations of such relationships and there are a few cases where a fault seems to have been used, as on Olifantsfontein 20 (Sheet 51—Bethal) about 9 miles NW of Delmas.

The ridge of Daspoort quartzites between Onbekend and Zwavelspoort provides us with a test case of such relationships (Fig. 3, "RPNM"). This part of the Daspoort Quartzite forms a ridge about 500 feet above the highest part of the Pienaars River valley. Since there are patches of the tillite still to be found on the floor of the valley we can conclude that the Pienaars River has re-excavated a pre-Karroo valley (eroded by the Carboniferous ice) between the Daspoort and Magaliesberg quartzites. Two left-bank tributary streams of the Pienaars River derive from the high ground west of the Daspoort Quartzite and cut well-defined gaps in the quartzite before they reach the broad Pienaars valley. One of these tributary streams flows along a fault and cuts its poort where the fault-plane is transverse to the ridge, at Zwavelspoort (Fig. 3, "M").

The second lateral stream, higher up the course of the Pienaars River, cuts through the Onbekend ridge at Tiegerpoort, where, at the poort itself, there is no fault. Tiegerpoort is less deeply cut than Zwavelspoort and originally was a double gap, cut by two streams: one with its headwaters flowing southwards and one flowing northwards. The northward-flowing stream is the stronger and has recently beheaded the southward-flowing stream at the poort, leaving a well marked wind-gap now about 20 feet above the elbow of capture ("N" in Fig. 3).

The decision as to whether these two streams at Zwavelspoort and Tiegerpoort are superimposed across the Daspoort quartzite or whether they have cut back through it by headward erosion can scarcely be arrived at by the character of these poorts alone. But other features in the ridge nearer to the Karroo surface, throw strong light on the processes involved. On the farm Klipkop 503 a tributary of the Tiegerpoort Spruit is now cutting back into the Daspoort quartzite and has produced a little kloof or valley in the ridge which is very clearly the beginning of a poort of the Tiegerpoort type ("P" in Fig. 3). As yet there are no definite stream courses in this kloof but two courses are beginning to take shape: one to the north and one to the south, with a part of the quartzite between them containing no trace of a stream course and very closely corresponding to the knoll in the middle of Tiegerpoort. In this embryo gap one can see what the initial stages of Tiegerpoort must have been, and after seeing Klipkop 503 one can have little doubt that Tiegerpoort is a gap formed by headward erosion and not by superimposition.

Still further south along the Daspoort ridge and adjoining a remaining patch of tillite, a well-defined fault-plane cuts across the Daspoort quartzite obliquely ("R" in Fig. 3). A headwater of the Bronkhorst Spruit has cut back near this fault-plane for a short distance but the upper part of the ridge, which is affected by the fault, does not yet contain a stream course. At the crest of the ridge the fault is revealed clearly by the effect of weathering and sheet-water erosion, for although there is no stream course, weathering and sheet-water erosion have removed a good deal of the surface, and along the fault line a stream course is certain to develop soon. This, then, appears to be one process of development along a transverse fault and the probability is very great that Zwavelspooit was formed in this way—by post-Karroo erosion along the transverse fault and not by superimposition.

THE WITWATERSRAND SURFACE.

The surface of the Witwatersrand, with the adjacent surface of the Ventersdorp lava, provides another example of drainage in process of being superimposed and also of the difficulty of relating that process to a surface which has been stripped for some time of the imposing formation In the eastern part of the Witwatersrand streams rise generally on the Karroo surface and are now cutting into the older surface wherever it is being exposed. The middle and western part of the Witwatersrand surface has for some time been denuded of whatever Karroo covering it may have had and already the drainage arrangement presents difficulties of interpretation. It is again best to consider first the area where the Karroo beds are still in place and then to pass to the denuded surface.

On the Eastern Witwatersrand the process of superimposition is shown simply in a few places to the north-west and north-east of Benoni and also to the south and south-west of Boksburg. In the Benoni area the Dwyka tillite is covering the Orange Grove and Observatory quartzites which are gradually being exposed by the erosion of the stream rising on Witkoppies 7 (Geological Sheet 51, Johannesburg) and flowing through Rietpan 1 and Kleinfontein 2. The quartzites here have obviously been planed by the Carboniferous ice sheet and, at the margin of the Karroo surface the older surface is flat or undulating, with no ridges marking the quartzite outcrops. The older surface here is part of the pre-Karroo glacial peneplain(5). The shallow valley already cut in the exposed " window " of these Witwatersrand beds is about 2,000 yards wide and 170 feet deep. Where the stream has cut down into the Observatory quartzite there is no ridge at the outcrop of the quartzite but the surface is strewn with boulders and here and there along the outcrop the quartzite is forming a somewhat jagged surface: obviously the early stages of a ridge.

Fig. 4.—The first stage in the excavation of a poort in the pre-karroo surface. Looking west along the outcrop of the Orange Grove quartzite striking across the valley of the Kleinfontein Spruit, 3 miles N.W. of Benoni. In the background the Karroo surface on Witkoppies 7.

A mile or so further up this shallow valley the Orange Grove quartzite is also being uncovered and the beginnings of a poort and a ridge are discernible here too (Fig. 4).

This is an unquestionable superimposition of the simplest form and the later stage must inevitably be the deepening of the valley, forming poorts or gaps in the harder quartzites which will eventually become ridges. The ridge and poort thus begin here also as excavated features.

On the southern margin of the Karroo surface, to the south-east of Boksburg, a set of poorts in the Elsburg Quartzite show the gradual development of such superimposed features very clearly. These poorts have already been described(7) as showing stages in superimposition from the first stage on Witpoortjie 12 (east) where the stream has only just begun to reveal the Witwatersrand surface, through the next stage, in the western gap on Witpoortjie 12, where the valley has been cut to a depth of about 30 to 40 feet. In these two gaps on Witpoortjie 12 the process of superimposition is in its earliest stages and the Karroo beds are being gradually removed, leaving the same type of excavated poort as those already described to the north of Benoni. To the south-west of Boksburg the Karroo beds have been completely removed from the Elsburg quartzite, but this gap, on Leeuwpoort 4, is without doubt a further development of the same type of feature, and at Elsburg village itself, a few miles west of Leeuwpoort, the gap is still a stage deeper and wider. The deepest and topographically most advanced poort development is at Alberton where the stream has cut into the quartzites to a depth of over 300 feet. The Alberton Spruit gap is somewhat complicated by a probable capture above the poort, but it seems to owe its origin to the same causes as the spruits further east—to superimposition from the Karroo surface.

In the middle part of the Witwatersrand the only traces of the Karroo covering are at Booysens, between the northern and southern ridges, where a patch of the Ecca and Dwyka beds still exists. In this middle portion, however, the present drainage is not of the superimposed type, but is directly related to the structure of the Witwatersrand System. The main watershed is on or near the Observatory Quartzite, and the longitudinal valley between this quartzite and the Elsburg ridge to the south is obviously a pre-Karroo feature.

The main difficulty here is to account for the rather abrupt easterly terminations of the Elsburg and Klipriversberg ridges. In the east these ridges stop abruptly a few miles west of the Alberton Spruit but more gradually on the west near the Klip Spruit. Between these spruits the ridges rise to levels similar to those of the northern ridges of the Witwatersrand.

The drainage associated with these two southern ridges in the Middle Rand, the Elsburg Ridge and the Klipriversberg, is definitely not of the superimposed type, but of the simple headwater-erosion type. Even the shoulders of the poorts at Ormonde 18 and Turffontein 19 (Wellington, 1924: 26) seem clearly to be due to the accession of water when the headward-eroding streams tapped the resources of the Elsburg quartzite.

In this middle area of the Rand there seems to be no indication of a superimposed drainage. There are no neks or cols in the Klipriversberg or Elsburg ridges which could not better be accounted for on the basis of structure or headward erosion. It seems that between the Alberton Spruit in the east and Klip Spruit in the west we are dealing with a part of the Rand in which, for some reason, there has been no process of superimposition. It there has been such a process in this area all recognisable traces of it have by now been obliterated.

Associated with the Witwatersrand in drainage type is the Heidelberg area to the S.E. where the Blesbok Spruit and Zuikerboschrand Spruit are the two principle lines of drainage(8). The upper course of the Blesbok Spruit has been imposed on the underlying dolomite, the Karroo beds forming a very shallow covering in this part of the eastern Rand, and the valley is a continuation of the glacially-excavated valley between the two ridges of the Timeball Hill Quartzite to the SSE of Pretoria. Rogers points out that the lower course of the Blesbok Spruit also occupies a pre-Karroo valley, the section showing that this valley is a broad and shallow hollow, probably excavated by the ice-sheet between the resistant Ventersdorp lava on the NW and the harder parts of the Witwatersrand System to the SE(8). The higher parts of the pre-Karroo surface have been denuded of the Karroo beds which, however, still thinly cover the hollowed parts of the pre-Karroo surface.

Rogers also draws attention to the fact that the major stream courses are independent of the structure, whereas the minor courses tend to occupy fault planes and structurally weak zones. This agrees with the conclusion reached above in connection with the Daspoort quartzite between Onbekend and Zwavelspoort.

Perhaps the most striking case of drainage superimposition is to be seen in the Vredefort region where the Vaal has cut a course generally transverse to the circular ridges of the

Witwatersrand quartzites. This relationship has been described by Hall and Molengraaff(⁹) and also by Nel(¹⁰) who point out that whereas the main stream courses are discordant with the structure, the minor or tributary valleys conform closely with the zones of structural weakness in the pre-Karroo surface.

SUPERIMPOSITION ON INLYING PLATEAUS AND RIDGES.

The cases we have considered have all been of superimposition on older surfaces marginal to the Karroo System. There are examples, however, of streams now being imposed on hard pre-Karroo rock surfaces which, by denudation, are beginning to project above the surrounding Karroo surface.

Typical examples of this are the felsite masses shown in the Bethal geological sheet about 15 miles to the north of Bethal, where the Olifants River is clearly imposed upon the felsite surface ("F" in Fig. 1). At present the surface of the felsite rises about 300 feet above the surface of the Karroo formation surrounding it, but at some distance from the felsite the highest points on the Karroo surface are approximately equal in altitude to the highest parts of the felsite. There can thus be no doubt that the Olifants River has been imposed on the felsite. The effect is striking. Whereas the Karroo beds have been weathered around the felsite and removed comparatively rapidly by stream erosion, the felsite itself has weathered much more slowly and the Olifants is now cutting in it a narrow, deep valley which contrasts remarkably with the more open country above and below the felsite. We thus have here the beginnings of a river-course transverse to a plateau or isolated mass similar to the more advanced stages seen in the Zuikerbosch Rand or in the isolated granophyre mass through which the Crocodile River cuts to the north of Brits.

The felsite outcrop referred to is not an isolated instance of the beginnings of such a process; a second example of the same type is seen about 10 miles to the west where the Riet Spruit is beginning to cut a similar deep valley or gorge through a rather smaller felsitic outcrop. The process of superimposition is here obviously in its earliest stages.

GENERAL CONCLUSIONS.

It is, of course, impossible to establish general and universal principles of superimposition from the examination of one particular type of imposing formation and one type of receptive surface. In respect of the area under consideration however, we may arrive at certain general conclusions which may or may not agree with superimpositional relationships elsewhere. The more important points seem to be:

1. THE MAIN DIVIDE. At the present stage the main watershed is post-Karroo in the east and pre-Karroo in the west (Fig. 1). Between these extremes is an intermediate zone (between Boksburg and Delmas) where a main watershed is being evolved by superimposition from the highest parts of the Karroo surface.

2. TYPES OF RECEPTIVE SURFACES. Karroo drainage is being imposed on three types of surface—plateau (Waterberg), transverse ridge (Pretoria and Witwatersrand quartzites) and isolated mass or ridge (Felsite inliers).

3. STRUCTURAL ZONES. Zones of structural weakness in the older, receptive surfaces do not generally affect the courses of newly-imposed streams, although such zones and such stream-courses sometimes do coincide.

4. PRE-DENUDATIONAL POORTS. A superimposed stream may cut a poort or ridge near to a pre-denudation gap which it may ignore.

5. TWICE-CUT RIDGES. A superimposed stream sometimes cuts and re-cuts through a hard bed, thus forming two or more poorts in the same ridge.

6. FAULT-PLANES. A fault-plane transverse to a pre-Karroo ridge, when not coinciding with a superimposed stream course, weathers as a nek or col, which may later become the site of headwater courses developed on the denuded, older surface.

7. DOUBLE POORTS. The occurrence in a headwater-basin of a double poort in a ridge—i.e. a wide gap occupied by two separate streams—appears to be a headward-erosional feature rather than a superimpositional feature.

8. EXCAVATED RIDGES. Ridges formed by hard rocks in a receptive surface are generally excavated, in the sense that they originate as subdued parts of the older surface and are given prominence after the post-denudational drainage has reduced the softer rocks.

9. SUBSEQUENT DRAINAGE. Subsequent to the imposition of the main streams, tributary streams develop on the denuded, older surface whose courses are not of the discordant, superimposed type, but concordant with the structural zones of the older surface.

10. TYPES OF TRANSVERSE DRAINAGE. Transverse drainage which is superimposed is sometimes not easily distinguishable from the headward-erosion type but, as a corollary of 9 above, conformity of a stream-course to the structure of the denuded surface generally, though not invariably, indicates post-denudational development.

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A CHERT SEAM ASSOCIATED WITH THE FIRECLAYS AT LAWLEY, TRANSVAAL,

BY

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Read July, 1940.

Most current theories on the origin of fireclays do not adequately account for certain features of the South African occurrences such as the character of the organic matter or of the chert seams. The significance of the glacial phases at the base, usually not more than thirty feet below the fireclays, is also not fully realised. With these points in view, I have investigated the occurrence and character of these "minor" features of the deposits, before constructing any theory of their formation.

Wagner in 1916 described chert seams in the fireclay deposits at Olifantsfontein, as follows:—

> Reference must finally be made to the cherts which are undoubtedly the most puzzling rocks met with in the clay pit. They occur in layers ranging from half an inch to a foot or more. The chert is a dense fine-grained rock, the colour of which varies from white to dirty brown.

Wagner considered the chert to be Dwyka as it is associated with glacial erratics towards the bottom of the clay pit. It may be noted that in recent visits to this pit the glacial phases were no longer visible. The area exposed during Wagner's visits is now covered in.

OCCURRENCE OF THE CHERT SEAMS. The chert seams now described are in a deposit of the Anglo-Vaal Brick and Tile Co., about a quarter of a mile west of Lawley station. The fireclays and semi-refractory clays are situated about half to three-quarters of a mile to the north of the Company's main works. In Fig. 1 a section in this pit shows the manner in which the chert is found and its relationship to the fireclays. The chert is white in colour and generally stained by ferruginous material; it has the very blocky structure shown in Fig. 2. The rubble band is probably not glacial in origin as it passes into the soil above the Karroo rocks. As the fireclays have so far not been found below the Dwyka it is reasonable to assume that this rubble band is of very recent origin. The well rounded character of the boulders is noteworthy. The chert would, therefore, appear to be Ecca in age.

CHARACTER OF THE CHERT. The chert is very similar in micro-structure and chemical composition to the chert of the Dolomite Series(¹). A partial chemical analysis is given below:—

SiO_2	98·40
$\left\{ \begin{array}{l} Al_2O_3 \\ Fe_2O_3 \end{array} \right\}$	1·42
CaO	0·16
MgO	0·10
Loss on Ignition	0·37
	100·45

(Analyst. V.L.B.)

The macro-structure differs greatly from that of the cherts of the Dolomite Series and of other cherts in the Karroo System, recently described by Mountain and Frankel (³). Even on crushing to small particles the chert retains its "blocky" structure. The size of the quartz grains (which compose about 98% of the rock) varies considerably as in the cherts of the Dolomite Series. Laminations and finely disseminated carbon are absent and the characteristic conchoidal fracture of chert has not been observed.

AGE OF THE CHERT. As the fireclays are generally regarded as Ecca, this chert band must be younger than those described by Wagner. Although this is the only fireclay deposit where I have observed chert seams, continued work in other localities may expose other occurrences. The Lawley Ecca chert can in no way be confused with the cherts of the Dolomite Series. The latter are not only quite different in appearance as previously mentioned but occur in much bigger bodies. A geological map has been prepared of this locality and the relationship between the Karroo rocks and the Dolomite is fairly well known.

SUMMARY.

A chert associated with fireclays at Lawley is described. It is considered syngenetic with the clays, and as far as I am aware only this occurrence and that observed by Wagner have so far been recorded.

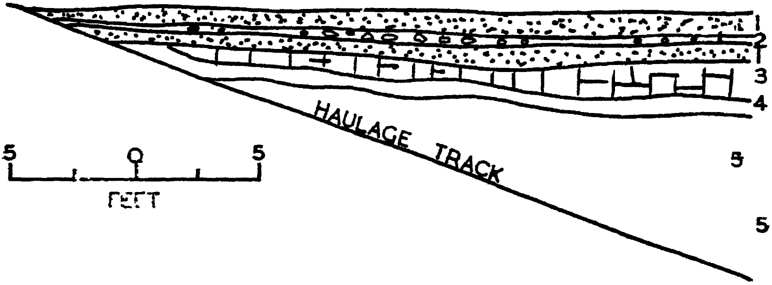


Fig. 1

1. Soil
2. Boulder Bed.
3. Blocky Chert.
4. Transitional Clay, Usually Red.
5. Unbedded Dirty White, Plastic Fireclay.

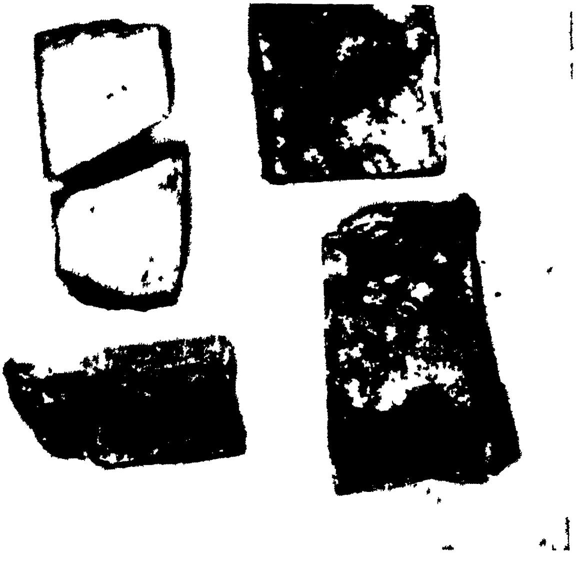


Fig. 2.
Blocky Chert from Lawley. (x1.5).

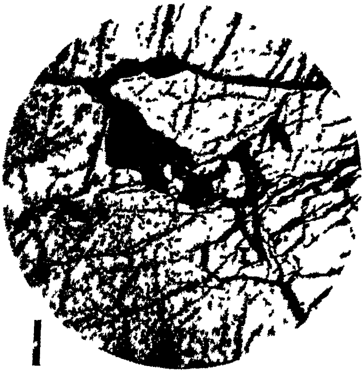
Methods for the determination of vanadium were investigated and the following method was adopted. One gram of ore was fused with ten grams of sodium carbonate and one gram of potassium nitrate, the cold melt extracted with water, a few drops of alcohol added and the solution cautiously boiled to precipitate manganese and filtered. The filtrate was neutralised, acidified with an excess of 10 mls. of dilute sulphuric acid, and taken to fumes. After cooling and diluting to 200 mls. the solution was made lukewarm, passed through a Jones Reductor and washed through with very dilute sulphuric acid. The reduced solution was collected in a flask containing a five-fold excess of ferric sulphate solution to which 5 to 6 mls. of syrupy phosphoric acid had been added. Titration was carried out against N/10 potassium permanganate solution. This method gives concordant results and is applicable when molybdenum and chromium are absent, although small amounts of the latter do not interfere.

Total iron in all samples was determined with potassium permanganate and titanous chloride and allowance made for the vanadium and titanium—the latter being determined by difference.

A macroscopic examination of the ore showed the presence of at least two varieties of material, one variety consisting of equigranular polygonal grains of average diameter 3 mm. fitting closely together with little interstitial material, fractured grains having a steel-grey metallic lustre; the other variety lacking well-defined boundaries between grains which are of a greater average size, have duller fractured surfaces; interstitial material, mainly ilmenite and hydrated iron oxides, is more abundant. The pulverised ore varies in colour from reddish brown through dark chocolate to black and analyses indicate that the variation is often due to the percentage of ferrous iron it contains.

Low power examination of the ore showed interlocking subhedral and polygonal whitish grey grains, with a small amount of interstitial grains and veinlets of associated minerals (figure 1). Some specimens are pinkish brown with roughly circular pale greyish white areas up to 2 mms. in diameter, merging into the main colour. On etching with conc. HCl the circular areas were unaffected (figure 2). A similar disposition of areas and grains were noted in other cases.

The minerals noted were: Maghemite, coulsonite, magnetite, ilmenite, haematite, martite, goethite, limonite (earthy goethite) and small amounts of silicates and chalcopyrite.



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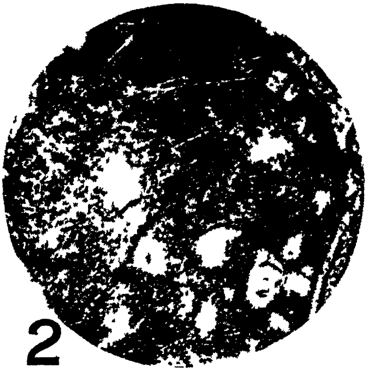

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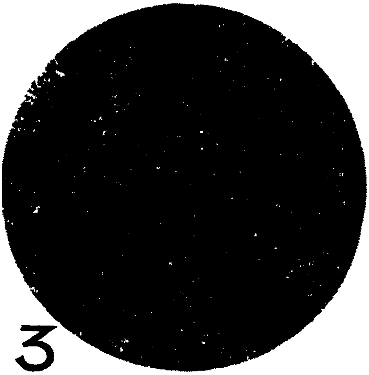
Fig. 1. General view of grey-white maghemite grains with limonite (L) and ilmenite (I). x 25.

Fig. 2. Etched surface of ore showing fine laths of ilmenite and ilmenite-maghemite intergrowths. x 14.

Etch tests tried on the dominant constituent of the ore the greyish white, isotropic, magnetic mineral gave negative results with all usual reagents. Concentrated HCl after long periods, sometimes gave a faint staining. Stannous chloride in HCl gave a rapid darkening, occasionally faster than the reaction of this reagent on haematite. But for the isotropic and magnetic nature of this mineral the etch reactions would suggest haematite. This magnetic form of ferric oxide had been described by American workers, and Wagner gave the name *Maghemite* to the form found in the iron ores of the Bushveld Complex. While the colour of maghemite is usually whitish grey, it appears to be slightly bluish white when near to, or in contact with haematite or martite. Occasionally, with oblique reflected light, a reddish brown internal reflection is seen. Under high power the apparently uniform maghemite shows an almost sub-microscopic intergrowth with ilmenite (figure 3). In addition, a large number of minute orientated ilmenite laths averaging 5 μ in width with a length of 18 μ are present. Another type of orientated lath-like, though somewhat lenticular inclusions occurs in the maghemite (figure 4), many of which are from 10 to 18 μ in length and consist of a white margin 0·5 μ wide surrounding a violet lens-like centre about 1 μ across. The margins, which appear to be anisotropic with a reddish brown internal reflection may be haematite; the centres may be rutile. Irregular areas of magnetite occur quite often in the maghemite (figure 4), and contain ilmenite in a fine intergrowth.



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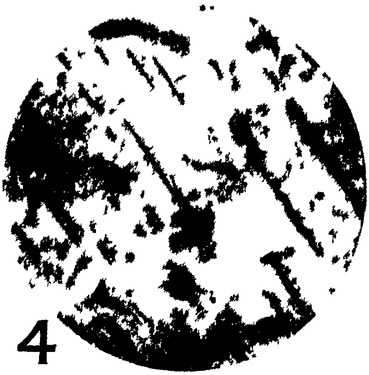

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Fig. 3. Etched surface of maghemite, showing fine intergrowth with ilmenite. (I) is coarser growth of ilmenite. x 840.

Fig. 4. Lens-like inclusions in maghemite (light grey), patches of magnetite, dark grey. x 800.

Quite a large number of the maghemite grains apart from the ilmenite laths, are under highest powers, free from the finest observable intergrowth. Several of these maghemite grains were removed from the polished sections and partial analyses made with the following results:—

Fe_2O_3	66·01	71·51	67·7	64·34
FeO	12·16	7·09	12·03	8·93
TiO_2	5·34	9·6	7·55	8·54
Cr_2O_3	0·35	n.d.	trace	trace
V_2O_3	0·5	0·99	n.d.	0·14

Norms (partial and approximate) Analyst J.J.F.

	%			
Chromite	0·6	—	—	—
Ilmenite	10·18	15·0	14·6	16·4
Magnetite	23·2	—	16·2	3·7
Haematite	49·6	71·5	57·6	61·4
Rutile	—	1·7	—	—

Chromite and rutile reported in most norms have not been identified in the polished sections—they are thus only normative minerals.

In three of the above analyses there is sufficient FeO to satisfy the TiO_2 for ilmenite and to allow for magnetite, but other analyses show insufficient FeO even for the TiO_2. Probably some solid solution of $FeTiO_3$ and Fe_2O_3 exists, or as suggested by Dunn and Dey (1937), "Ti can take the place of an Fe atom in the Fe_2O_3 cubic lattice at high temperatures, and can assume a cubic symmetry isomorphous with magnetite and maghemite." The amount of titanium in the maghemite, after allowing for the ilmenite laths, is about 10% (as TiO_2). Walker also inclines to the view that there is a magnetic oxide $(FeTi)_2O_3$. The small quantities of magnetite in the maghemite, suggest that alteration of the original magnetite or titano-magnetite is not quite complete.

Vanadium-bearing titaniferous iron-ores occurring in India have been the subject of a comprehensive study by Dunn and Dey. In these ores vanadium reported as V_2O_3 varies from just over 0·5% to as much as 7%. The authors found that the vanadium is present in a mineral *Coulsonite* isomorphous with magnetite. The search for Coulsonite was greatly helped by a study of one of the sections used by Drs. Dunn and Dey kindly supplied by the Indian Geological Survey.* In South African material examined up to the present, the amount of V_2O_3 rarely exceeds 1%. Therefore, unless the element is concentrated in minute areas, the detection of a definite vanadium-bearing mineral in the polished sections will be almost impossible. The properties of our maghemite are strikingly like those given for coulsonite, but microchemical tests for vanadium were often negative or barely positive. In some sections rich in magnetite, small whitish grey areas consisting of a mixture of ilmenite and haematite (?) laths in a bluish grey mineral taken to be maghemite (figure 5) are common. Powder obtained from these areas by drilling with a fine dental drill gave strong positive tests for vanadium whereas tests on the magnetite were usually negative. Those areas of which probably 50% consist of the latter mineral occupy about 9 or 10% of the ore surface; V_2O_3 determined in a portion of such a polished section was 0·73%; the amount of V_2O_3 in the bluish grey mineral is therefore about 15% and nearly equal to that suggested for coulsonite. In the analyses of individual maghemite grains, given above, the vanadium content is variable and not as high as that assumed for true coulsonite. Dunn and Dey have suggested that coulsonite may well be a vanado-maghemite instead of a vanado-magnetite; i.e. $(FeV)_2 0_3$ rather than $Fe0. (FeV)_2 0_3$. This suggestion is supported by our results and it is suggested that the term "Coulsonite" might be applied to maghemite which is rich in vanadium. Finally, the possible existence of a complex Ti-V-Fe oxide may be considered.

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* Obtained for us by Mr. V. L. Bosazza.

Magnetite occurs as irregular patches in the maghemite grains, the transition from the pinkish brown of the former to the grey white of the latter being fairly distinct. In the magnetite-rich portions of the ore, however, the pinkish brown very gradually merges into the grey white maghemite, the ilmenite portion of the intergrowth remaining undisturbed. The mineral composition deduced from analyses usually compares favourably with that observed under the microscope. Two samples of titaniferous iron ore from the Western Transvaal were partially analysed as follows:—

	1.	2.
$Fe_2 0_3$	47·78	39·46
$Fe0$	27·67	29·42
$Ti0_2$	14·72	16·83
$Cr_2 0_3$	1·20	1·88
$V_2 0_3$	015	0·14

1. West of Pilansberg. (Analyst G.W.G.)
2. Farm, Haakdoorndrift, No. 165. (Analyst J.J.F.)

Partial and approximate Norms:

	%	%
Chromite	1·0	2·9
Ilmenite	25·8	32·2
Magnetite	42·6	41·8
Haematite	19·2	10·4

These ores consist essentially of a fine intergrowth of magnetite and ilmenite with an octahedral arrangement of coarser ilmenite laths (figure 6). The high titanium content is expressed in the rather large amount of interstitial ilmenite present. In both these ores minute and rare areas occur in which the pinkish magnetite is replaced by a white mineral which is not etched by conc. HCl or aqua regia. This mineral gave a faint positive reaction for vanadium in microchemical tests of powder obtained by drilling. Maghemite and haematite are almost entirely absent from these two ores, which closely resemble the Indian ores in the constituents of intergrowths and in mineral composition. The pink- or rose-brown magnetite is generally distinct from the more violet tinged brownish ilmenite, which takes a similar polish, but in the Western Transvaal ore coarse laths of ilmenite are often invisible in the magnetite. An approach in colour between magnetite and ilmenite may indicate high titanium content and suggests the presence of titano-magnetite. Some irregular patches of magnetite appear to be free from ilmenite laths (figure 7).

Ilmenite occurs (1) as grains often twinned and interstitial between earlier formed grains; these represent the largest particles of the mineral in the ore, grains 5 x 13 mm. having been noted; (2) as a constituent of a fine intergrowth with maghemite and magnetite; (3) as irregular blebs in the main ore mass, often surrounded by altered maghemite; (4) as veinlets in which haematite laths occur in Widmanstätten pattern; (5) as coarse uniform laths in Widmanstätten pattern or parallel arrangements in the main ore mass (figures 7 and 8).

Ilmenite usually has its characteristic violet brown colour, but the shade varies from minute laths to larger grains probably owing to a varying titanium content in ilmenite of different ages. For example, interstitial ilmenite is a shade darker than the irregular blebs which again are darker than the ilmenite in the veinlets.

Haematite as an original constituent of the ore is small in amount. It occurs as laths 1 μ in width, in veinlike bodies of ilmenite, and perhaps in the white grey areas which contain coulsonite. It also occurs as thin irregular veinlets up to 50 μ wide cutting through the maghemite and ilmenite grains. Small irregular remnants of haematite are also found in veinlets of hydrated iron oxides.

High or moderate ferric oxide percentages shown in analyses need not be due to maghemite. Most of the iron ores examined were obtained from outcrops in which iron minerals may have been oxidised to haematite (martite) and hydrated oxides. Martite is less common in maghemite-rich ore than in ore containing much magnetite; it is distinguished from maghemite by its lighter colour and anisotropism. Martite occurs along the margins of ilmenite veinlets and in cracks in the more weathered ore. It may replace maghemite along grain margins and it replaces the magnetite portion of an intergrowth without disturbing the ilmenite network (figure 9). In addition, it occurs in a Widmanstätten pattern radiating into magnetite grains from cracks or veinlets (figure 10).

Goethite occurs in the more weathered ores in bluish veinlets averaging 0·2 m.m. in width, between and across grains. It is either well crystallised with strong anisotropic effects (figure 11), or in colloform structure. This latter form gives a more intense reddish brown internal reflection than the more compact variety. A fibrous patch observed in the goethite in one section may be lepidocrocite. The veinlets are often bordered by thin margins of haematite. It was found that after treatment with fuming perchloric acid the goethite was deeply etched and had a rough yellow-brown surface.

A large number of irregular areas and veinlets between grains contain structureless red- or yellow-brown limonite which does not take a polish. The internal reflection of this material is very marked. In some very weathered outcrops, limonite is the dominant mineral and only isolated remnants of maghemite occur.

Finally, somewhat oval-shaped specks of chalcopyrite 1 to 2 μ in width are distributed throughout the ore and small irregular areas of silicate gangue minerals are also present.

The authors consider that the intimate association of the minerals in this ore would militate against the successful concentration of any of its constituents by physical methods.

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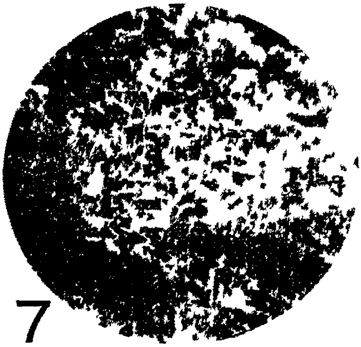

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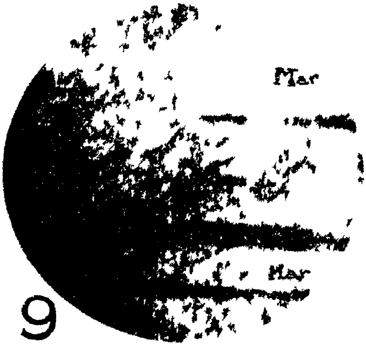

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Explanation of Plates.

Fig. 5. Etched surface of a greyish white area seen in figure 2. Lighter intergrowth consists of ilmenite, haematite and coulsonite. Darker portions are intergrowth of ilmenite and magnetite. x 800.

Fig. 6. Octahedral arrangement of coarse ilmenite laths in a fine magnetite-ilmenite intergrowth. x 300.

Fig. 7. Irregular areas of magnetite (Mag) surrounded by martite (Mar). Ilmenite (I) also present. x 480.

Fig. 8. Ilmenite laths in maghemite. Nicols partly crossed. x 100.

Fig. 9. Alteration of magnetite (Mag) in a magnetite-ilmenite network to martite (Mar). Dark laths are ilmenite. x 1000.

Fig. 10. Etched surface of maghemite with radiating martite (Mar) developing. Irregular patches of ilmenite (I) surrounded by martite. x 480.

Fig. 11. Veinlet of crystalline goethite under crossed nicols to show strong anisotropism. Minute veinlets of goethite are also present in the ilmenite grain shown light grey. Maghemite is the black grain. x 350.

NEW MODIFICATIONS FOR DETERMINATION OF THE EQUIVALENT WEIGHTS OF ORGANIC ACIDS AND BASES

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FERTILISING NATURAL VELD AND ITS EFFECT ON SWARD, CHEMICAL COMPOSITION, CARRYING CAPACITY AND BEEF PRODUCTION

BY

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African Explosives and Industries, Limited.

With Two Text Figures.

Read 2 July, 1940.

Introduction.

In 1933 a grazing experiment was laid out by the Botanical Department of the Witwatersrand University at their Frankenwald Research Station, on an area of virgin veld grazed intermittently in the past by native cattle, and African Explosives and Industries were requested to co-operate in the soil fertility and productive aspects.

The veld in this area consists mainly of *Tristachya hispida*, *Trachypogon plumosus* and *Digitaria tricholaenoides* as the dominant species, with *Heteropogon contortus*, *Brachiaria serrata*, *Eragrostis chalcantha*, *Tristachya Rehmannii* and several others as minor species, growing on a badly drained, poor, coarse sandy soil of granitic origin. Nitrogen and phosphates are deficient in this soil, potash and lime are low and the pH ranges from 4·5 to 6·0. The carrying capacity of this veld in its natural condition is low, being less than one beast to the morgen for the summer season. The rainfall is about 30 inches per annum.

OBJECTS OF THE EXPERIMENT.

The objects of the experiment were to study the effects of various fertiliser treatments on (1) the sward in general and the botanical composition of the veld, (2) the yields and chemical composition of the herbage, with special reference to the protein and phosphate contents, (3) the carrying capacity of the veld, and (4) the live-weight gains of beef steers.

METHODS AND TECHNIQUE.

The fertiliser treatments applied originally to the ten two-morgen camps were O, Ca, P, PCa, PN, PNCa, PNK, PNKCa, PN_2K and PN_3K where P=400 lbs. of a superphosphate and rock phosphate mixture, N=200 lbs. sulphate of ammonia and K=80 lbs. chloride of potash per morgen once annually. In the PN_2K treatment an extra dressing of nitrogen, as 200 lbs. sulphate of ammonia, was given at mid-season and in the PN_3K treatment a third dressing at the same rate in early autumn. The Ca camps received a dressing of 2000 lbs. agricultural lime per morgen once every five years.

Throughout the course of this experiment the original fertiliser applications have in general, been adhered to, though minor alterations have been introduced. Thus, in the 1936-37 season, after four fertiliser applications, only nitrogen was applied and no phosphate or potash. Again, from 1937-38 season onwards, fertiliser mixtures have been substituted for separate applications of individual constituents.

Grazing took place from some time after the first effective rains of early summer, usually November or early December, until the end of the growing season, which was April or early in May, depending on rainfall and temperature. The method of grazing adopted in the first years of the experiment was to put a convenient number of native cattle into one or more camps when the grass was ready for grazing, irrespective of the fertiliser treatments. The cattle remained in the camps until the grass was consumed, avoiding as far as possible over and under-grazing, and were then moved to other camps. The number of cattle days of grazing so recorded was credited to each camp in turn as it was grazed. Data were obtained in this way also, with Ayrshire dry cows and heifers in the 1934-35 season and with Sussex-Afrikander steers in the 1936-37 season. In all seasons adjustments were made in the calculations for small stock such as calves, young heifers and donkeys.

The shortcomings of this method were fully discussed in a previous paper dealing with a portion of this experiment by the present writers (1937: 275 and 276). Consequently, in 1936, a cattle weighbridge was installed so that a check could be kept on the weights of animals in the experiment. Also, from the 1937-38 season onwards, the PN_2K treatment was changed to PN_3K and the PN_3K treatment to PN_3KCa. This allowed five treatments to be compared: viz. O, P, PN, PNK and PN_3K and by subdividing the two-morgen camps, it was possible to obtain four one-morgen camps of each treatment, of which two of each treatment were also limed.

This scheme made it possible to allot a given number of animals to each treatment and graze them for the whole season in the four camps, thereby allowing closer study of the live weight gains as affected by the different fertiliser treatments. The disadvantage of this method was the change from an intensive to a more extensive system of grazing with possibly too few animals at the peak period and too many towards the end of the season, but, this was found to be the most reliable way of obtaining accurate data on beef production.

All data presented on live-weight gains are based on fortnightly weighings on three successive days at more or less the same time in the morning, before watering. The number of animals placed in the different groups was calculated from the average grazing day figures for two seasons, and for 1937-38 the groups were: O and P: three steers each; PN and PNK: four steers each; and PN_3K: six steers. In the 1938-39 season seven steers were placed in the PN_3K group, and four morgen of a mixed pasture of Rhodes Grass and *Paspalum dilatatum* were included in the experiment with 9 steers. This mixed pasture received the PN_3K fertiliser treatment and in this paper the group is referred to as PN_3K-F. This number of steers on the PN_3K-F treatment was found to be too high and in the 1939-40 season the groups were as follows: O and P: 4 steers each; PN and PNK: 5 steers each; PN_3K and PN_3K-F: 6 steers each Halfway through this last season, there were several deaths due to sickness and the O and P groups were reduced to three steers each, so that numbers in the other groups could be maintained.

The cattle were watered in the morning and late afternoon and between waterings were placed in a shade camp, where salt was available but no grazing. Dipping took place at fortnightly intervals, except in the last season when it became necessary to dip at weekly intervals for some weeks. Hand dressing was also done when necessary.

With regard to the study of botanical changes and the composition of the sward, detailed work on this phase has been done by the Witwatersrand University—Murray (1934) and Glover (1936)—and more data will be reported elsewhere in due course. In addition to this, however, observations have been made by the writers from time to time and notes taken periodically on the species comprising the sward.

In order to obtain information on the effect of fertiliser treatments on the yield and chemical composition of the herbage, the camps were closed to grazing in 1935-36 and representative areas harvested at intervals. The results of that season's work have been published by the writers (1937: 275). Again in 1936-37 samples were collected at random from temporarily protected square yard areas in each rotation and in 1938-39 samples were taken from each camp from several two square yard areas just before grazing in each rotation. In every case an attempt was made to obtain samples of herbage representative of that eaten by the grazing animals. Samples thus obtained were air-dried and subsequently analysed.

EXPERIMENTAL RESULTS.

EFFECT OF FERTILIZERS ON THE SWARD. As far as the results of treatment on the sward are concerned, only general observations need be given here. In general the treatments have shown that care must be exercised in the management of fertilised pastures as increased palatability and bulk mean increased numbers of cattle grazing very closely. Some species are likely to suffer in this way, while others may spread In the unfertilised camps changes did not appear to be so marked. There is a further difficulty in the grazing of small camps without water as trampling of the veld around gates, which amounts to a considerable fraction of a 1 morgen camp, has a harmful effect on the sward. As the fertiliser treatment and consequently the rate of stocking increases, this damage necessarily becomes more evident.

Taking the experiment as a whole *Digitaria tricholaenoides* has increased in amount and *Tristachya Rehmannii* has tended to disappear These observations are confirmed by van Rensburg (1939: 238). In the heavily fertilised camps *Eragrostis spp.* and *Harpechloa falx* have increased and some camps have been invaded by *Hyparrhenia hirta.* Weeds, such as *Stoebe vulgaris* and *Erigeron canadensis* have notably increased in some camps, although *Zizyphus zeyheriana* has decreased. Where trampling is noticeable *Cynodon dactylon* has increased and a certain amount of *Aristida spp.* and *Chloris virgata* is noticeable. It has not been observed, however, that carrying capacity or palatability have been adversely affected by these changes.

YIELDS AND CHEMICAL COMPOSITION.

The average yields of herbage and chemical composition of the dry matter are shown in table 1 for the years 1936-37 and 1938-39.

TABLE I. Composition of Veld Herbage based on dry matter at 100°C.

1936–37 season. 1938–39 season·

Treatment.	Dry matter per morgen. lbs.	Crude protein. %	P_2O_5 %	K_2O %	Dry matter per morgen. lbs.	Crude protein. %	P_2O_5 %
O	3319	6·96	0·17	1·17	5114	6·61	0·19
P	4387	6·99	0·31	1·14	4889	6·77	0·38
PN	5706	7·88	0·32	1·37	5552	7·86	0·38
*PNK	6067	7·87	0·32	1·45	5901	8·01	0·36
*PN_2K	5150	8·80	0·33	1·60	—	—	—
PN_3K	5985	9·00	0·28	1·59	4957	9·92	0·35
PN_3K-F	—	—	—	—	5682	11·08	0·53

* One camp only of each in 1936-37.

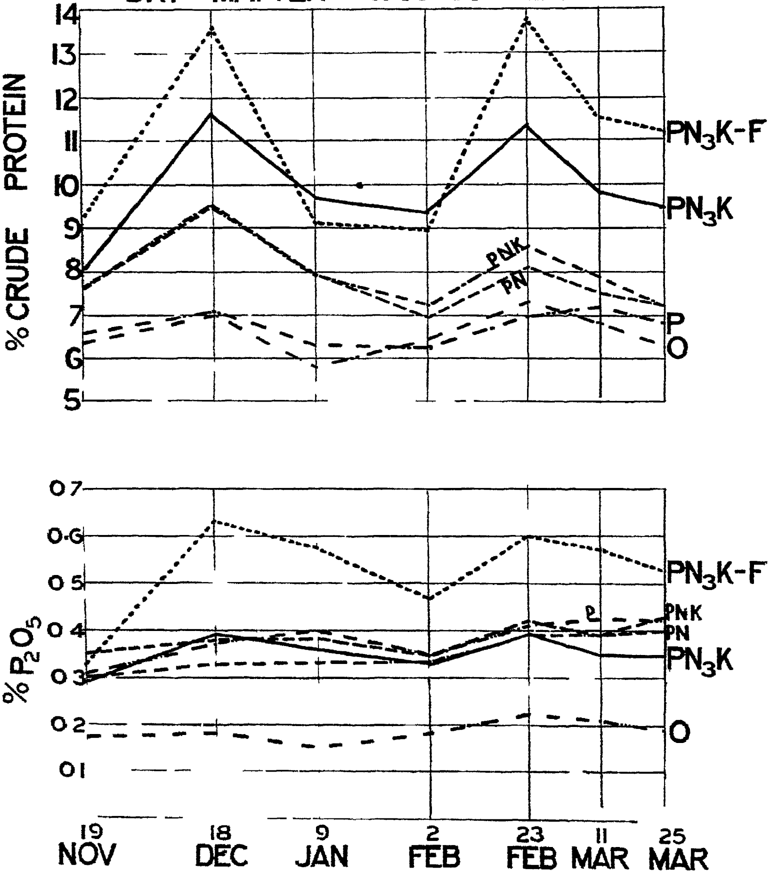
The seasonal variations of protein and phosphate for 1938-39 are shown graphically in Fig. 1.

THE CARRYING CAPACITY.

The results as far as the carrying capacity of the veld or the number of grazing days per morgen is concerned may be summarised as shown in Table II. This table gives the grazing days per morgen of mature beasts for every season in which grazing took place, the average for the six seasons, and a comparison of the average with that of a rate of stocking of 1 beast to the morgen for 180 days.

FIG I

FRANKENWALD PASTURE EXPERIMENTS
COMPOSITION OF HERBAGE BASED ON DRY MATTER 1938-39 SEASON



AVERAGES OF FOUR CAMPS

Liveweight Gains of Blei Steers

The summarised results of cattle weights are presented in table 3 as groups or treatment increases in live weight for three seasons These group gains represent the increase produced by four morgen of pasture for the summer grazing season without any supplementary feeding

TABLE II Summary of Cattle Grazing Days per Morgen.

Treatment	1933–34	1934–35	1936–37	1937–38	1938–39	1939–40	6 year average	Equivalent to beasts per morgen for 180 days
O	178	224	115	102	100	150	145	0·80
P	207	203	134	102	100	150	149	0·83
PN	230	245	181	136	133	214	190	1·05
PNK	241	250	194	136	133	214	195	1·08
*PN_2K	271	229	204	—	—	—	235	1·30
*PN_3K	282	259	241	204	233	257	246	1·36
PN_3K-F	—	—	—	—	272	257	265	1·47
Seasonal Rainfall in inches	38·52	29·68	32·65	26·05	28·76	28·45	7 year average 31·49	

TABLE III Group Live weight Gains and averages per head

	1937–38 136 days)		1938–39 (133 days)		1939–40 (171 days)	
Treatment	Group gains in lbs	Daily average per head.	Group gains in lbs.	Daily average per head.	Group gains in lbs	Daily average per head.
O	489	1·19	562	1·40	311	0·52
P	615	1·50	598	1·49	253	0·42
PN	914	1·68	1064	2·00	908	1·06
PNK	841	1·54	1050	1·97	736	0·86
PN_3K	1706	2·09	1819	1·95	1479	1·44
PN_3K-F	—	—	1573	1·39	1135	1·11

These increases are shown as composite curves in Fig. 2, which gives the average group gains over three grazing seasons.

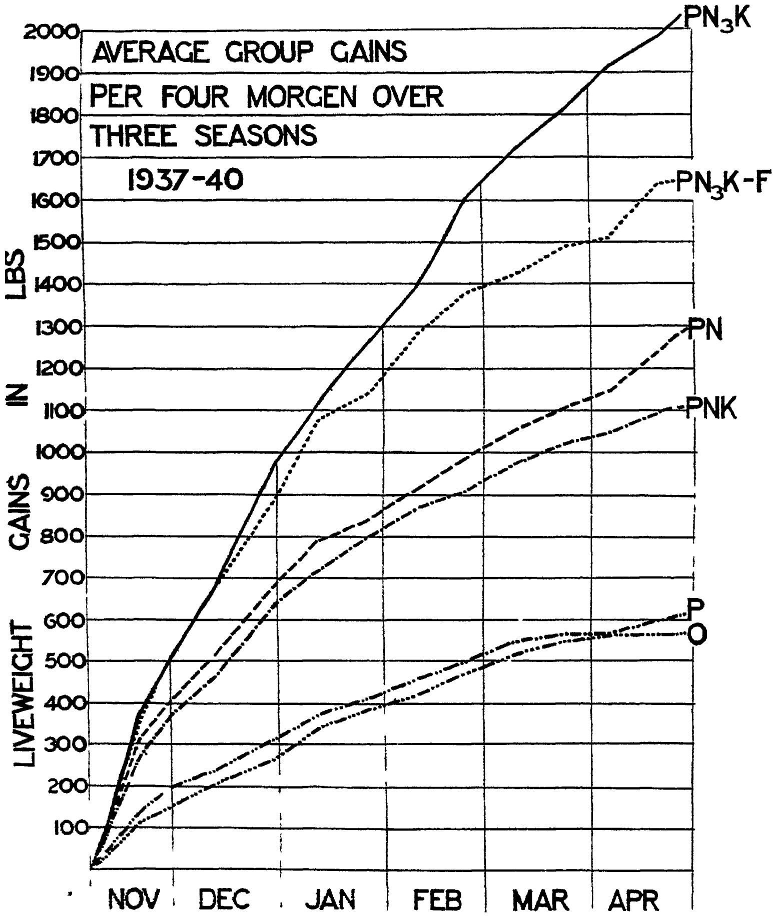
DISCUSSION OF RESULTS: EFFECTS ON THE SWARD.

The changes in the sward apparent from general observations have already been mentioned. From these changes it would appear that the grazing of small camps heavily fertilised calls for judicious management, but in larger camps under farming conditions many of the tendencies observed in this experiment would not be so important or so marked. In this experiment, annual mowing and two burnings have been resorted to in an attempt to control selective grazing which is evident under fixed rates of stocking, but even with large groups under intensive management it is certain that occasional mowing would be necessary.

The view that intensive grazing of fertilised veld camps leads to exhaustion of root reserves and hence botanical changes is not supported by any scientific evidence. In fact

FIG 2

FRANKENWALD PASTURE EXPERIMENTS



Weinmann (unpublished Mss. 1940) in studies carried out on these plots, has shown that fertiliser treatments increase the nitrogen and phosphate content of the roots.

It has been observed that several typical sourveld species, such as *Elyonurus argenteus* and *Trachypogon plumosus* give good early spring grazing though they are unpalatable later when more mature. Other species such as *Brachiaria serrata*, *Digitaria tricholaenoides* and *Tristachya hispida* shoot somewhat later and give excellent spring and summer grazing.

Harpechloa falx which increased fairly rapidly on all nitrogen camps, is palatable in mid and late season.

From the results obtained thus far it appears that a sward of several species such as this can be maintained at a productive level for the whole summer season provided the food value is kept up by regular fertilising. Furthermore, with controlled intensive grazing it is possible to maintain the sward in a stable condition. Around gates and in a few areas of palatable grasses amid less desirable ones there are zones of overgrazing. in which Cynodon, *Aristida spp.*, *Eragrostis spp.*, *Chloris virgata* and other annuals have made an appearance. This does not necessarily mean that the camps have deteriorated from the grazier's point of view.

THE YIELD AND CHEMICAL COMPOSITION OF HERBAGE.

Although there is not a high degree of correlation between fertiliser treatments and increased yields of herbage, due most probably to the limitations of the methods of sampling, the carrying capacity figures show that bulk must have been considerably increased.

In a sward of this nature where the total grass cover amounts to less than 25% in the best camps, increased production of herbage is not easily seen unless very marked. Fertilised camps, especially those receiving nitrogen, can be picked out however from a distance on account of the deeper green colour and are leafier and softer under foot.

The chemical analyses of the herbage, as shown in Table I and Fig. I, indicate that nitrogen has given an increased protein content. This increase has been maintained throughout the season, so that the grass has a higher food value not only in the flush period of early spring but also up to the end of the grazing season when the food value of the unfertilised veld has dropped considerably. It is of great practical value to know that the protein content of veld grasses can be kept at a fairly high level throughout the season by regular applications of sulphate of ammonia, thus enabling farmers to save on concentrates which are fed in some cases to supplement veld grazing from the end of January onwards.

The results also show that the phosphate content of the grasses can practically be doubled by phosphate applications. The influence of potash on the content of this constituent is not very marked nor is that of lime on the lime content.

In general the data thus far obtained show a definite improvement in the feeding value of this type of veld for summer grazing dependent on the fertiliser treatment; this is at variance with the views of Rowland (1938: 96).

The results shown in table I and fig. I are of further interest when studied in connection with the authoritative contribution by du Toit and others (1940: 229-32) on the nutritive value of the natural pastures of South Africa. According to the standards given by them, the grass on the unfertilised camps has not enough phosphorus for growth requirements of cattle except for a very short period and only enough protein for limited growth. The grass on all the camps getting phosphatic fertilisers, however, has a high enough phosphorus content for normal growth for the entire grazing season. This applies also for the protein on all the camps getting nitrogen, while the two sets of camps getting three dressings of nitrogen are above their highest standard all the time. The growth curves shown graphically in fig. 2 bear out the above statements to a marked degree. The phosphate-only treatment shows slight though definite superiority to the control throughout but is obviously limited by the protein shortage.

CARRYING CAPACITY.

The grazing day returns as summarised in table II show that there have been responses to all fertiliser treatments containing nitrogen.

In the last three seasons with fixed rates of stocking, the returns obtained show conclusively that fertilisers have increased carrying capacity and that in spite of higher stocking, individual daily gains are also greater.

Comparing the O and P treatments, it is seen that apart from doubling the phosphate content, the phosphate-only treatment has given a very small increase in carrying capacity. Similarly, a comparison of the returns from the PN and PNK treatments show a very small increase in grazing days as a result of the potash applications. This increase is too small to be of any significance. From this it is clear that nitrogen in the form of sulphate of ammonia in the presence of phosphate has given the largest increase in carrying capacity.

As a general conclusion, it may be stated that with regular applications of nitrogen and some phosphate to raise the phosphate content, the carrying capacity of this poor type of sour veld, without any other treatment, may be almost doubled.

LIVE-WEIGHT GAINS.

The live-weight gains of the steers used, have shown a more definite relationship to fertiliser treatments than yields of herbage, and the weighing of the animals at regular intervals is more reliable than the method adopted for taking samples of the herbage. In fact, the steers have been better samplers and their synthetic metabolism confirms herbage analysis.

In connection with the group gains and daily average gains for three seasons, presented in table III, it must be pointed out that in all three seasons the animals used—Sussex-Afrikander crosses and grade Aberdeen-Angus—have been three years old or under. They have thus been growing as well as increasing in weight and yet some of the early season daily gains are striking. (See table IV in appendix.) The lower returns in the 1939-40 season can be ascribed to sickness which interfered considerably with the results although the Aberdeen-Angus steers this year were of the best quality and most uniform in age and conformation.

The results show that phosphate applications have given slight response. The PN and PNK treatments have given practically the same result and show no response to potash. The superiority of the PN treatment in all three seasons may possibly be due to slight differences in the camps and not necessarily to any depressing effect on the part of the potash.

A comparison of the PN and PNK treatments with the O and P treatments show clearly the effect of a single dressing of 200 lb. sulphate of ammonia per morgen in practically doubling the liveweight gains. The further increases given by the PN_3K treatment confirm these results, showing the importance of nitrogenous fertilisers in producing from 3 to 4 times the yield of beef from the same area of veld. An examination of table I and fig. 1 shows how these gains are closely correlated with the increased crude protein content of the herbage due to the nitrogen dressings.

With regard to the economic aspect, it should perhaps be pointed out that when this experiment was initiated, it was felt that this type of veld was so poor and unproductive that it would never be profitable to fertilise it, and consequently the economic aspect was not given much consideration. The experiment was in fact, considered more of academic than of practical importance. It is of great interest to note, however, that if the increases in live weight gains over the no fertiliser treatment are valued at 30/- per 100 lbs. the PN_3K treatment is the only one to show a return over the cost of the fertiliser treatment. If the potash were omitted, and as far as we are able to ascertain its addition is unprofitable, a better case still can be made for this treatment.

The fact that the artificial pastures in two seasons have not given results as good as the veld receiving the same fertiliser treatment, is contrary to expectation, particularly in view of the higher phosphate and protein contents of the grass as shown in the 1938-39 season. An explanation for this is probably to be found in the effect of dry weather on these camps, for they suffered more than the veld in hot, dry periods and took longer to recover after conditions became favourable again, and did not grow as much or so steadily during a drought. They did, however, produce higher gains for short periods of favourable climatic conditions, particularly in late autumn. This suggests that these grasses could best be used for hay and silage and should be grazed chiefly in late summer.

It is perhaps significant also that two of the four camps in this group have been established on old squatter lands.

The results emphasise, however, the value of a good sward of veld grasses and show that veld should not be ploughed up for establishmenet of artificial pastures without due consideration.

AVERAGE DAILY GAINS PER HEAD.

The daily gains as averaged fortnightly are presented in Table IV. They are illuminating in several aspects. Firstly, the enormous gains of the animals in the first fortnight of early summer are most striking. They have of course had a railway journey and come straight from ranching conditions and in all cases were young growing steers. In the first two seasons, the phosphate-only camps show up well over the no fertiliser ones. Secondly, in all three seasons, the initial gains on all the camps getting nitrogen are much the greatest, varying from thirty to nearly one hundred per cent. increase in spite of heavier stocking. During the second fortnight the gains decline considerably.

During the 1939-40 season, the superiority of the nitrogen camps was strongly maintained into the fourth fortnightly period, but after this, continuous sickness made the gains somewhat erratic. During this season, on account of three-day sickness and particularly virulent attacks of gall-sickness and red-water, the average annual gains are the lowest, yet the percentage benefit from the nitrogen camps is considerably higher than in the previous seasons.

After the end of the grazing season on the 25th April, 1940, all the steers as one group grazed on the aftermath of several fertilised sown pastures, comprising Rhodes grass and *Paspalum dilatatum* mixtures and various Digitaria species It is worthy of note that the three animals from the no fertiliser plots gained by far the most when they got the opportunity on these well fertilised pastures. The phosphate-only group were next best, showing a good response to the nitrogen. The other groups excepting the PN_3K-F did badly. During the next fortnight, all the animals as one unit were rotated through all the veld camps used in this experiment. As will be seen, there is a remarkably consistent loss of around 2½ lbs. per beast per day despite there being ample grass available in the camps.

These results show that although fertilised veld gives better gains than unfertilised veld, there is nevertheless a decline in rate of growth as the season comes to an end, as shown by the writers (1937: 278) and there is a steady decrease in protein and mineral content and in the daily rate of gain of steers, although these effects are lessened by the extra nitrogen dressings in the PN_3K treatment. After frost even fertilised veld of this type not only produces no gains but causes actual losses in weight. It is thus clear that the higher feeding value of fertilised veld of the type described in this paper is not maintained in winter after the first frost when the grasses built up root reserves for the next season's early growth.

SUMMARY.

(1) A grazing experiment on sour veld twelve miles north of Johannesburg on the Botanical Research Station of the Witwatersrand University is described. In this experiment unfertilised veld is compared with veld fertilised in different ways, by means of botanical observations, yields and chemical composition of herbage, carrying capacity expressed as grazing days, and live-weight gains or losses of beef steers.

(2) Data are presented showing how fertilisers increase the yields of dry matter and crude protein, nearly double the phosphate and increase the potash content by from 20 to 30%. Nitrogen is shown to give the greatest response in dry matter and crude protein production.

(3) Carrying capacity data for six seasons show that significant increases have been given by fertiliser treatments, while the heaviest dressing has practically doubled the carrying capacity. The chief increase is from the initial dressing of nitrogen, equivalent to 200 lbs. sulphate of ammonia per morgen. Two subsequent dressings at the same rate gave somewhat lesser increases, but the highest total protein, production, and daily gains. The equivalent of beasts per morgen has been raised from 0·80 to 1·36 for the summer grazing season.

(4) Fertilised veld camps receiving three dressings of nitrogen have given liveweight increases in beef steers practically four times as great as those produced on equal areas of unfertilised veld. Average daily gains per head have been two to three times greater in this treatment than those from animals on unfertilised veld. The beneficial effects of the phosphate and nitrogen dressings are shown to a remarkable degree in the initial fortnight of each season.

(5) Contrary to expectations, mixed pastures of *Rhodes grass* and *Paspalum dilatatum* receiving the same fertiliser treatment as the most heavily fertilised veld proved inferior to veld as far as total liveweight increase per unit area and average daily gain per head were concerned. Their advantages, however, have been fully discussed.

(6) Changes in the botanical composition of the cover brought about by treatments and the system of management are briefly described. Although some botanical changes have taken place, particularly on the high nitrogen camps, it has not been observed that they are detrimental to production and in spite of the intensive grazing, the cover on the camps is better now than when the experiment started.

(7) The results of grazing fertilised veld of this type in winter show that the increased feeding values brought about by fertiliser treatments are not maintained after the first frosts of winter.

APPENDIX

TABLE IV. DAILY GAINS OR LOSSES PER HEAD OVER 3 GRAZING SEASONS.

1937—38 SEASON.

lbs. per head for head for period ending :—									Annual Average Daily Gain.
12 Jan. 14 days.	26 Jan. 14 days.	9 Feb. 14 days.	23 Feb. 14 days.	9 Mar. 14 days.	23 Mar. 14 days.	6 Aprl. 14 days.	20 Apl. 14 days.	27 Apl. 7 days.	136 days.
1·8	1·5	2·0	1·2	0·7	0·9	0·0	0·2	0·4	1·19
2·0	1·8	2·5	0·6	1·6	0·8	0·3	0·8	0·8	1·50
2·2	2·0	2·5	1·3	0·9	0·9	0·8	0·6	0·5	1·68
1·5	2·4	2·1	0·4	1·1	0·9	0·4	0·3	0·0	1·54
2·5	1·9	2·5	2·3	2·0	1·4	2·1	0·3	1·2	2·09

1938—39 SEASON.

30 Nov. 14 days.	13 Dec.* 13 days.	29 Dec. 16 days.	11 Jan. 13 days.	25 Jan. 14 days.	9 Feb. 15 days.	22 Feb. 13 days.	8 Mar. 14 days.	22 Mar 14 days	6 Apl. 15 days.	133 days.
0·71	2·69	0·75	2·69	0·78	1·88	2·20	1·11	0·90	0·75	1·40
2·02	2·43	1·52	3·41	0·45	1·28	1·51	1·19	0·66	0·00	1·49
2·46	3·99	2·54	3·66	0·53	1·40	2·34	1·05	1·23	0·46	2·00
2·75	2·90	2·79	3·11	1·26	1·76	1·17	1·21	1·41	0·00	1·97
2·30	2·70	2·71	2·03	1·88	1·20	2·51	1·10	1·21	0·48	1·95
2·92	2·88	1·91	3·65	0·50	2·25	1·00	0·73	0·49	0·27	1·74a

1939—40 SEASON.

6 Dec 14 days.	20 Dec. 14 days.	4 Jan. 15 days.	17 Jan. 13 days.	31 Jan. 14 days	14 Feb. 14 days.	28 Feb. 14 days.	13 Mar. 14 days.	27 Mar. 14 days.	10 Apl. 14 days.	25 Apl. 15 days.	171 days.	25 Apl. to 9 May. Daily gain or loss per head over 14 days on aftermath of sown pastures.	9 May to 24 May. Daily loss per head over 14 days on veld camps after frost.
1·60	0·30	0·13	1·23	0·07	—2·16	2·33	0·00	0·35	0·31	—0·38	0·52b	2·62	—2·17
1·75	—0·06	—0·40	0·39	0·39	—0·45	1·21	0·33	—0·47	—0·12	1·19	0·42b	1·86	—2·19
2·20	1·10	0·30	—0·06	0·55	—0·26	0·97	0·94	0·51	0·87	1·50	1·06	—0·06	—2·46
2·20	0·75	—0·52	0·14	0·44	—0·28	0·83	0·63	0·45	1·23	1·13	0·86	0·48	—2·73
2·30	1·80	1·50	0·37	1·89	0·66	3·18	—0·45	0·77	1·07	1·44	1·44	—0·15	—2·64
2·15	2·00	1·40	0·45	0·87	0·56	1·74	—0·73	2·09	—1·07c	0·31	1·11	1·63	—2·69

*—Owing to drought, all groups grazed in outside veld during this period.

a—Average worked out on 8·5 steers, as one animal died 11 2 39.

b—Average worked out on 3·5 steers, as numbers reduced from 4 to 3 halfway through season in order to keep up numbers of other groups.

c—One sick animal in this group lost 110 lbs. in 14 days.

ACKNOWLEDGMENTS.

The authors desire to acknowledge with many thanks the assistance and co-operation of Professor John Phillips and his staff and students of the Botany Department of the University of the Witwatersrand during the seven years these experiments have been in progress. The assistance rendered by the University of Pretoria in providing facilities for the analysis of grass samples is also gratefully acknowledged.

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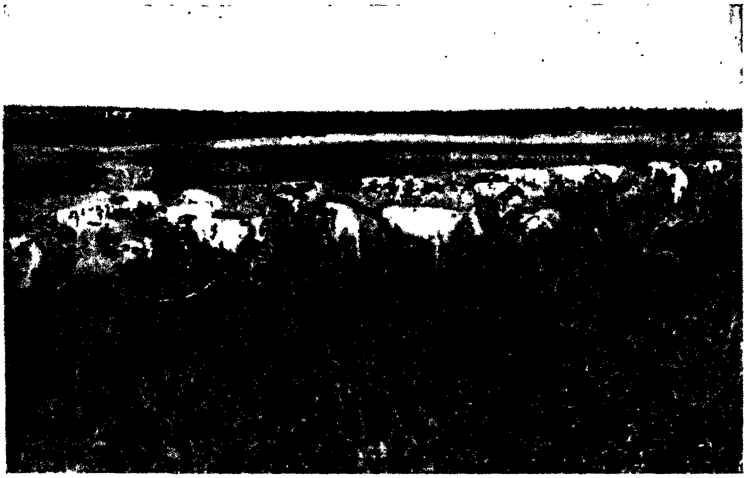
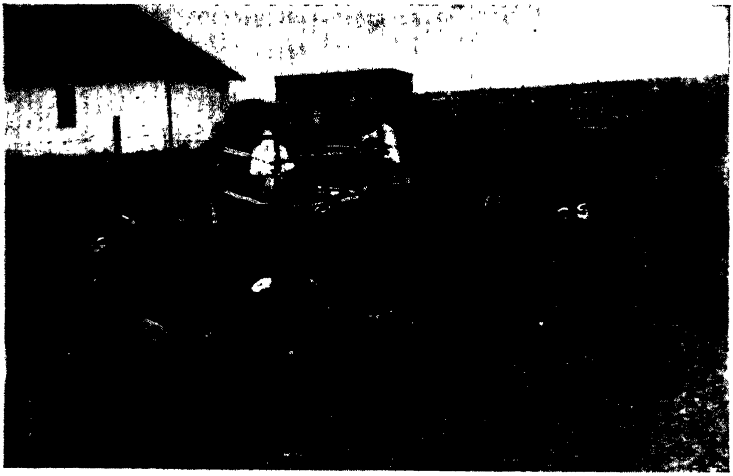


(1) Ayrshire Heifers and dry cows used in rotational grazing in 1934-35 to obtain grazing day returns.



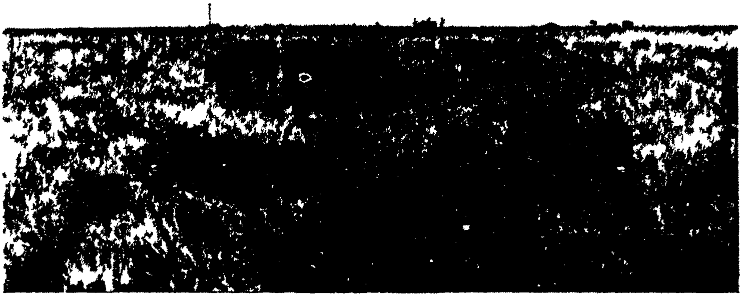
(2) Weighing experimental cattle, Frankenwald 1936-37.

(3) Type of steers used in the 1936-37 season

(4) Type of Steers used in the 1938-39 season

(5) Groups of Steers in the PN_3K-F treatment on a Rhodes and Paspalum Camp in 1938-39

(6) The control group in the 1939-40 season



(7) The PN_3K group in one of its camps in the 1939-40 season.

(8) Another view of the PN_3K group in one of the camps in the 1939-40 season. Note the Harpechloa in full seed in a damp area.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol XXXVII, pp.* 130-132.
February, 1941.

METAXENIA IN CARICA PAPAYA L

BY

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Read July, 1940.

Metaxenia is defined as the influence exerted by the pollen beyond the embryo and the endosperm, while xenia usually refers only to changes brought about in the tissue of the embryo (Nebel, 1930).

It was found, after the examination of some crossed fruit of *Carica papaya*, L., that black and grey seed occurred side by side and evenly distributed throughout the seed cavity This should not be confused with the distinct patches of black and grey seed which are sometimes observed and which are probably determined by other factors than those reported in this paper. Of 4,386 seed counted in four crossed fruits which were obtained from different trees, 3,274 were greyish and 1,112 black. This is a close approximation of a 3 : 1 ratio (P = ·50-·70), and suggests that grey is dominant over black. In 7 other fruits, 3,149 of the seed were grey and 3,243 black, which approaches a 1 : 1 distribution (P = ·20-·30). Hence it is concluded that seed colour is probably determined by a single factor pair.

The difference in colour can only be observed in the fresh seed since only the tough gelatinous skin enclosing the seed seems to be affected. This skin breaks up and shrivels when the seed is dried and apparently does not form an integral part of the embryo.

According to the hypothesis of sex determination in *Carica papaya*, L. developed by Hofmeyr (1938), the genetic constitution of the pistillate plant is m m and of the staminate plant M_1m. The factor symbols B, b are herewith respectively assigned to grey and black seed.

Some of the black and grey seeds obtained in the backcrosses reported above were planted in separate rows and the plants developing from them were then classified for sex. (Tables 1 and 2).

In Table 1 the results are reported of the backcross m m B b x M_1m b b, and a very good fit to a 1:1:1:1 ratio is obtained, (P = ·30–·50).

Table 1: Progenies of the cross m m B b x M_1m b b.

Pedigree No.	M_1B	M_1b	m B	m b	P value for 1:1:1:1 ratio
744	21	19	20	16	·80-90
745	16	11	12	13	·70-·80
749	17	10	16	10	·30-·50
750	14	14	14	13	·99-1
	68	54	62	52	·30-·50

The segregation of the progenies of the reciprocal cross, mmbb x M_1mBb, show a significant deviation from a 1:1:1:1 distribution, (P = <·01), which indicates that some other factors than those of chance variation have caused this distortion.

Table 2: Progenies of the cross m m b b x M_1m B b.

Pedigree No.	M_1B	M_1b	m B	m b	P value for 1:1:1:1 ratio
747	9	19	22	11	·10-·05
748	10	16	17	5	·02-·05
	19	35	39	16	<·01

These results suggest a linkage in the repulsion phase between sex and colour of seed, and hence the percentage of crossing-over with its standard error is found to be 32·1 ± 4·5.

The use of seed colour as a means to control the sex ratio of seedlings in the seedbed should become of considerable practical value to the grower. Additional data are, however, needed to confirm the above observation on sex linkage beyond any reasonable doubt.

SUMMARY.

Preliminary results suggest the occurrence of metaxenia in the gelatinous skin enveloping fresh papaya seed. A linkage of 32·1 ± 4·5 per cent. was observed between the genes B, b for grey *vs.* black seed and sex. The practical importance of the use of seed colour as a means of partial control of the sex ratio of seedlings is suggested.

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SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVII, pp.* 133-135.
February, 1941.

A STUDY OF THE EFFECTS OF EUCALYPTS ON THE SOIL, THEIR NUTRIENT REQUIREMENTS, AND TRANSPIRATION

BY

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Read July, 1940.

INTRODUCTION.

The genus Eucalyptus is of interest and importance, not only from an economic point of view, but also from chemical, physiological and systematic aspects. In a poorly-forested country, such as South Africa, eucalypts are of value in the production of timber, since they are fast growing; they are also used extensively as wind-breaks. It is held that eucalypt plantations dry up the soil very rapidly, and may even cause erosion in arid areas, since, by their heavy demands on the soil they prevent the growth of most types of ground vegetation. It is therefore of importance to ascertain whether eucalypts have a more detrimental effect on the soil than the indigenous vegetation, and under which conditions, climatic and otherwise, this effect is most manifest.

SITE CHOSEN FOR INVESTIGATION AND METHODS EMPLOYED.

Most of the experiments and observations were conducted at the Witwatersrand University Botanical Research Station at Frankenwald, where there are plantations of eucalypts of different species adjacent to grassveld and indigenous communities such as *Acacia caffra, Zizyphus mucronata* and *Gymnosporia buxifolia*. Thus comparisons of these different communities with regard to their effect on the soil are readily made.

Values were obtained for the water-content of the soils over a long period by means of total moisture-content determinations at weekly intervals, from samples taken at different levels in selected pits situated in eucalypt plantations, in adjacent grassveld, and in adjacent indigenous scrub consisting of *Acacia caffra* and *Gymnosporia buxifolia*. At first the results from pits selected in eucalypt plantations were only compared with those from similar ones in adjacent grassveld and maize-fields, but later samples were taken from pits under indigenous trees to provide a direct comparison between various classes of trees. Bisects, or trench quadrats were made in the eucalypt plantations, and also in the Acacia scrub and *Gymnosporia buxifolia* group, in the vicinity of the respective pits. This type of bisect gives a clear indication of the levels at which most of the roots occur, in relation to the depth at which the soil samples were taken. In addition, chemical and physical determinations were made of the soils at the different levels in the selected pits.

CONCLUSIONS.

Soil-moisture determinations have shown very great differences between soils in the eucalypt plantations and indigenous scrub, pointing to the fact that, while the indigenous trees, such as *Acacia caffra* and *Gymnosporia buxifolia* appear to conserve moisture, the eucalypts appear to do just the reverse, their demands on the soil-water-content being so great that the development of ground cover is much reduced and there is little or no conservation of soil moisture. In the group of *Acacia caffra* trees, with the comparatively thick undergrowth causing deposition of humus and ultimately an increase in the water-retaining capacity of the soil, the situation is the reverse. Chemical determinations show a much lower content of nitrogen, phosphorus and potash in the soil of the gum plantations, possibly an indirect effect of the roots of the eucalypts on the soil immediately surrounding them as regards phosphates and potash.

NUTRIENT REQUIREMENTS OF EUCALYPTS.

Young plants of *Eucalyptus robusta* of approximately the same size, history and vigour were grown, under natural conditions of sunlight, rainfall, wind, etc., in drums 2′ x 1½′ and 4′ x 2½′ containing definite quantities of soil of which the chemical constituents were known. At the end of two years the trees were removed, weighed and measured and the soil again analysed. It was found that the plants responded almost equally to identical conditions of amounts of soil, water and space. The trees in the small drums were nearly equal in size and weight but much smaller than those in the large drums: in both series an almost negligible amount of soil nutrients had been removed by the two-year-old eucalypts.

TRANSPIRATION STUDIED BY MEANS OF THE TORSION BALANCE.

The transpiration of the leaves of young eucalypts was studied by means of phytometer tins, in which the trees were grown in definite quantities of different types of soil, and under different conditions of soil-moisture-content. By this method very interesting and significant results were obtained, correlating transpiration with external conditions such as light intensity, temperature, evaporation, etc. An attempt was made to study transpiration by means of a specially modified torsion balance to measure loss of weight, but the instrument proved to be unsuitable for field work on account of its sensitivity to the slightest breeze. Transpiration could however be measured in the laboratory by this balance and was found to be constant for constant conditions of temperature, light-intensity and age. (Old leaves were found to transpire less than young ones.)

Although eucalypts appear to impoverish the soil, the chief cause of their destructive effect on other vegetation is the removal of large quantities of water from a considerable area by their shallow and spreading root system. It would be unwise to plant eucalypts near a water-supply, or to plant crops too near eucalypts used as windbreaks, and in very dry areas erosion might result from the removal of the soil moisture, impeding the growth of the ground vegetation which protects the surface soil from being washed away. On suitable sites, however, eucalypt plantations need not be considered a menace.

SUMMARY.

A brief account is given of the nature of the work carried out over several years on the effects of Eucalyptus spp. on soils. It is concluded that Eucalypts reduce soil water and certain solutes, where rainfall is not high. Certain indigenous plants reduce soil water to a lesser degree.

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February, 1941.

DISEASES OF FRUIT TREES CAUSED BY LEAF-RUST, MANGANESE AND ZINC DEFICIENCIES, AND THEIR JOINT CONTROL

BY

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(In co-operation with the Western Province Fruit Research Station.)

Read July, 1940.

Two diseases of fruit trees in the western Cape Province have in recent years increasingly commanded the attention of the grower and the plant pathologist alike. The one commonly known as "Little-leaf" or "Rosette" overseas as well as in this country, is the physiogenic disease caused by a zinc deficiency. The other is the leaf-rust disease of stone fruits caused by *Puccinia pruni-spinosae* Pers. Another deficiency disease, most appropriately designated as manganese deficiency mottle-leaf, was experimentally identified during the 1939-1940 growing season on a large number of plant species and shown to be of fairly common occurrence in the Stellenbosch and neighbouring districts of the Cape. A simple test such as used by Dickey and Reuther (1938) and one which can be most readily used by any grower, was employed for the identification of suspected manganese deficiency in plants affected by mottle-leaf. This consisted of dipping alternate leaves on an affected twig, or whole twigs, in solutions of manganese sulphate ($\frac{1}{2}$% or 1%), or of manganese sulphate (1%) plus hydrated lime (1%). Actively growing leaves should be selected for making these tests, as old leaves on deficient plants or trees, and those in which growth has already ceased, will either fail to respond at all or will be very slow in reacting to treatment.

On actively growing peach and apricot trees, positive results and complete recovery from mottle-leaf can be expected within a fortnight after treatment. Citrus trees on the other hand, appear to be somewhat slower in responding, although complete recovery was effected in mildly mottled leaves within four weeks after treatment with solutions of either manganese sulphate plus lime, or of permanganate of potash (¼%) plus hydrated lime (1%). Another successful but even simpler test employed on peach and apricot leaves with equally good results, was to put a number of droplets, about the size of a pin's head, of any of the above solutions in the chlorotic areas of the leaf. Positive response takes the form of small green spots on a chlorotic background, wherever the droplets have been put down. Growers in making such a test should of course tag all treated leaves, and some untreated leaves for comparison.

The list of plants showing mottle-leaf in which positive evidence of manganese deficiency was obtained by the above methods includes the following species of fruit trees: Plum (Santa Rosa, Kelsey, Sultan); nectarine (Victoria, Early Rivers, Gold Mine); peach (Elberta, Muir); apricot (Royal, Cape); citrus (Cape lemon, orange); chestnut; apple; grapevine and fig. Among the ornamentals responding to treatment with manganese, should be mentioned the rose, grenadilla (*Passiflora quintensis*), orange creeper (*Doxantha capreolata*), sunflower (*Helianthus annuus*), Kaffir honeysuckle (*Tecomaria capensis*), and the *Bougainvillea*. The only vegetables in which the disease has positively been identified, are the French bean (*Phaseolus vulgaris*) and the potato (*Solanum tuberosum*). Other species of plants such as the poplar, oak, poinsettia, pawpaw, and maize have shown a leaf mottling most suggestive of manganese deficiency. This, however, still remains to be proved experimentally.

The author has been unable to trace any published record of reports of manganese deficiency in plants in South Africa apart from a very brief illustrated article by Sutherst (1908) under the title: "Manganese Compounds as Fertilizers for Maize." In this the author does not report or describe any apparent deficiency symptoms on maize, but reports "considerable improvement in size and quality" of maize, by soil treatment with black oxide of manganese (pyrolusite), manganese chloride, and manganese sulphate, in pot experiments.

The leaf symptoms of manganese deficiency in different plants vary somewhat with the species but even in one and the same plant of a species the pattern produced may vary considerably from leaf to leaf. Only a very general description can be given here. The typical effect on the leaf is that

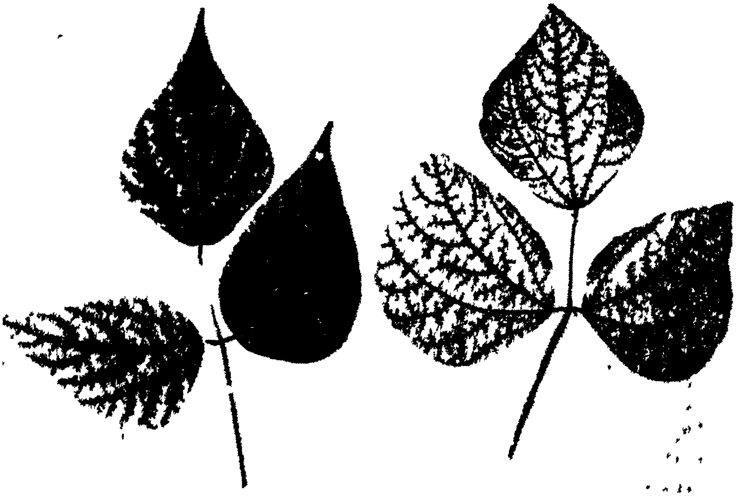

Fig. 1.—Various stages in the development of manganese deficiency in the leaves of the French bean. The leaves on the right show marginal scorch and complete chlorosis except for narrow bands of deep green on either side of the veins.

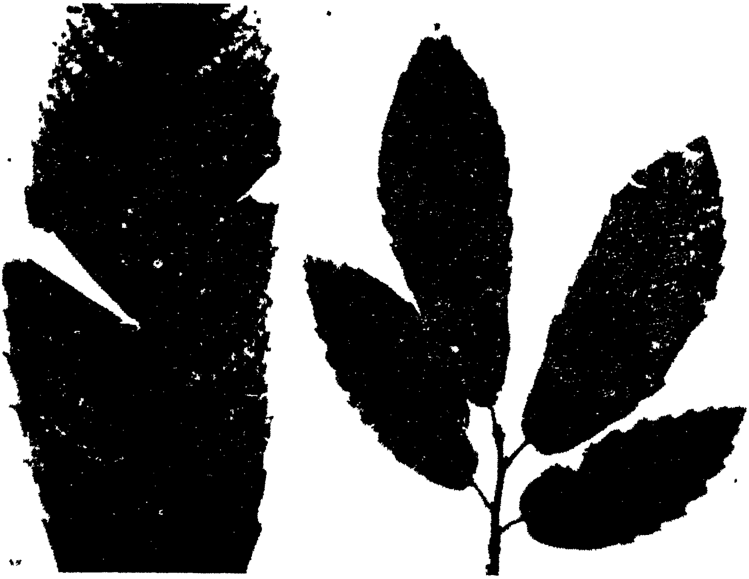

Fig. 2.—Manganese deficiency in the leaves of the chestnut. Chlorotic islands, some with necrotic centres are shown on the left. An extreme case of heat necrosis in deficient leaves is shown on the right.

of chlorosis, best described as leaf mottling. Mildly affected leaves may show no more than a mere trace of reduction in the normal green colour between the lateral veins on either side of the midrib, the inhibition of chlorophyll formation always being more intense towards the leaf margin. In severe cases almost the entire leaf may have been rendered chlorotic except for mere strips of green along the midrib and either side thereof, as well as on either side of the lateral veins, as shown in Figure 1. In intermediate cases between these two extremes the green colour is retained also along the cross veins between the lateral veins, thus forming chlorotic islands as illustrated in Figure 2. Under conditions apparently of extreme heat and water shortage in the plant, necrosis in the chlorotic areas may result, occurring either in the form of marginal scorch, or as necrotic spots in the chlorotic islands referred to above. This latter manifes-

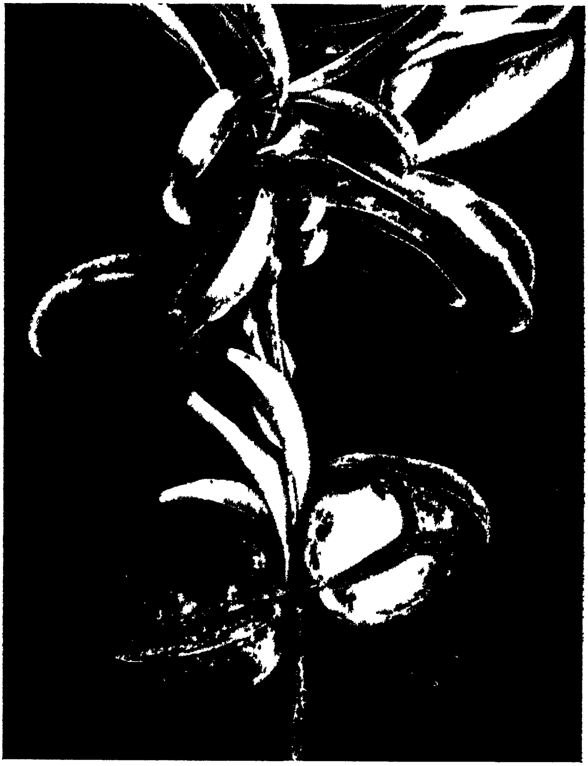

Fig. 3.—Severe cracking in the plums off the Santa Rosa tree illustrated in Fig. 5.

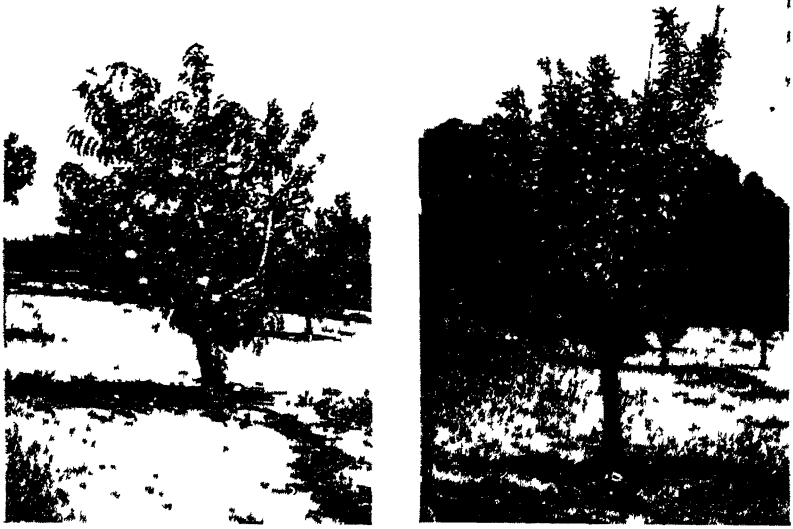

Fig. 5.—Die-back in the Santa Rosa plum (left), and Victoria nectarine (right) caused by a deficiency of manganese. Note the absence of any little-leaf symptoms.

tation is quite common on the chestnut, bean, and potato, but has not as yet been observed in the peach, nectarine, or apple.

No visual symptoms have thus far been encountered on the fruit of affected trees except a severe cracking in Santa Rosa plums on trees showing one hundred per cent. severe leaf-mottle as well as die-back, both of which conditions were due to a manganese deficiency. Figure 3.

On trees which had been injected with crystals of permanganate of potash and of manganese sulphate into the stems some five weeks before the plums began to ripen, not one per cent. of the fruit developed cracking as against 50 to 60 per cent. of cracked fruit on the control trees. The colour also of the plums on the treated trees was much earlier in developing and was a much more intense red. This chance finding, for the trees had been injected for the correction of mottle-leaf, is in agreement with the results obtained by Iverson (1938), who showed that the amount of fruit cracking in tomatoes could be significantly reduced by the application of permanganate of potash to the soil. The results obtained seem to point conclusively to a manganese deficiency as the cause of the specific instance of cracking of Santa Rosa plums, but further experiments will be carried out during the next season towards obtaining final proof.

Die-back of twigs as illustrated in Figure 5 is a manifestation that has been found to be associated with a severe manganese deficiency in nectarines, and Santa Rosa and Kelsey plums. In this connection it should be pointed out that none of the typical little-leaf symptoms as produced by a zinc deficiency precedes the die-back of twigs when caused by a manganese deficiency. On the tree as a whole the disease apparently can have a decidedly dwarfing effect, should a severe shortage of manganese arise early in the life of the tree.

The present position with regards to the zinc deficiency diseases—little-leaf, and leaf-rust of stone fruits in the Winter Rainfall area of the Cape Province can briefly be summarized as follows:

Both diseases are equally widely distributed but of the two, little-leaf is by far the most destructive. This disease does not only occur on the peach, plum, prune, apple, apricot, and pear, but also on grape-fruit trees in the Clanwilliam district where it has been encountered in its severest phase and has subsequently been corrected by the application of the zinc-lime treatment. Other varieties of citrus, too, quite generally show symptoms of zinc deficiency but with the little-leaf phase either absent or much less pronounced than in the stone fruits. It is no exaggeration to say, that more orchards, or a greater total of individual fruit trees in the Cape Province during the last decade have been rendered unprofitable or reduced to the point of being uneconomical by a zinc deficiency than by any other disease whatsoever. Such orchards have in some instances been abandoned or the trees taken out and the land put to some other use. Of paramount importance to the grower is that the disease should be diagnosed at an early stage and controlled by the application of zinc during the proper season of the year.

Brief surveys of the history and distribution of little-leaf in this country, together with descriptions of the little-leaf phase useful in the diagnosis of the disease, have already been given by Malherbe (1934) and Reinecke (1938). Apart from the descriptions referred to above, it may be pointed out that the disease has three developmental phases. The primary phase generally is known as mottle-leaf, a type of chlorosis in which one finds varying degrees of inhibition in the formation of chlorophyll in the areas between the lateral veins. The colour of the mottled leaf areas ranges from a lighter green than normal, through all shades of yellowing, to an almost white. A mild mottling does not necessarily affect the size of the leaf, whereas severe chlorosis induced by a zinc deficiency may have the most pronounced effect on the leaf size, hence the name little-leaf. Mottled and chlorotic leaves are very susceptible to spray injury and to high temperature injury which produce marginal scorch and necrotic spots which are usually scattered at random over the leaf surface. Heat necrosis in leaves affected by a manganese deficiency as a rule follows and is confined to the chlorotic areas of the leaf. One additional feature sometimes helpful in the identification of a zinc deficiency as the cause of mottle-leaf or chlorosis in some species such as the apple and peach, is the formation of a purplish pigment in and along the network of cross veins. This pigmentation sometimes also occurs in the lateral veins, and is best seen by reflected light on the under; i.e. dorsal surface of the leaf.

The secondary or little-leaf phase in the development of zinc deficiency symptoms is the most striking and typical feature of the disease. In this one finds an extreme reduction in the size of the leaves particularly in those from the terminal buds of the leaders. Leaves from buds for some distance below the tip of the leader may be similarly affected. In some cases a rosette of undersized leaves may be all that develops from the terminal bud, the buds lower down failing to put out leaves at all. The leaves in all such instances are either severely mottled or extremely chlorotic. In contrast to this, shoots and leaves from lower down on the branches may be quite normal in colour, size and growth.

The third phase of the disease can be described as die-back in the leaders affected by little-leaf in previous seasons. As the dead leaders and those otherwise affected continue to be removed in pruning from season to season, the tree may, in cases of extreme deficiency, contract in size within four or five years to a mere shadow of its former self.

The removal of many large limbs during each pruning season opens numerous channels of entry to wound-parasitic fungi. It is therefore not surprising to find that the fungus *Schizophyllum commune* commonly infects the main limbs and even trunks of a high percentage of trees which have on account of a zinc deficiency been subjected to the amputation of large limbs from year to year. These fungi help to finish whatever life is left in such trees. Were it not for this secondary invasion by wound parasites, affected trees, even when reduced to the state of dwarfs, might linger on for years, and even recover when given proper treatment with zinc compounds.

The symptoms of the various phases of zinc deficiency in fruit trees taken separately, might be easily confused with the symptoms of diseases having totally different causes. Mild leaf-mottle produced by a zinc deficiency and that caused by a manganese deficiency are, for instance, indistinguishable on peach or citrus leaves. Figure 7 illustrates a type of little-leaf on grape vines at the Cape, which formerly has been considered to be caused by a zinc deficiency, the more so because it was accompanied by leaf scorch and by die-back of the affected parts. This disease has now been proved by du Plessis (1939) to be bacterial in origin.

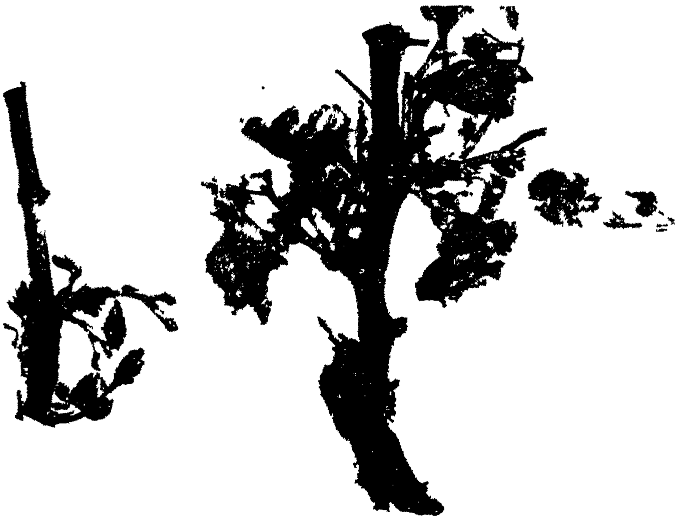

Fig. 7.—Illustrating a type of little-leaf accompanied by marginal leaf scorch, in the grape vine. This was formerly ascribed to a zinc deficiency but has recently been proved to be bacterial in origin.

The leaf-rust disease of stone fruits is well known to growers. It has always been troublesome to a greater or lesser extent on account of the premature defoliation which it causes in Prune d'Agen, all varieties of almonds, and certain varieties of peaches and of Japanese plums. Lately apricot growers in the Wellington district have also become greatly alarmed about its severity and extent in some orchards, and its spread to and increase in other orchards which they claim had been relatively free from rust until a few years ago. The Alpha variety being early is particularly subject to this disease, and the almost complete premature defoliation of this variety long before the end of summer now appears to be the rule rather than the exception in the Wellington district. Only this past season Alpha orchards were seen to have put on a full crop of new leaves by April, i.e. at the close of summer, and to be in blossom for the second time during one and the same season. The variety Royal, although just as susceptible as the Alpha to leaf-rust, appears to escape on account of its lateness much of the early infection to which the latter variety in adjacent orchards is subject. The Alpha for instance, blossoms and comes into leaf at a time when both temperature and moisture conditions are most favourable for infection and the further development of rust, whereas atmospheric conditions are relatively dry and hot by the time the Royal apricot begins to blossom and put out its leaves. The same can be said to apply to the very early varieties, such as King Edward, and the late varieties of peaches in this district. Both early and late varieties of susceptible stone fruits, however, are subject to severe attacks of leaf-rust late in the summer and during the autumn.

The cumulative effect of rust causing premature defoliation of fruit trees over a number of seasons, is considered to be in part responsible for the noticeable decline in the tree vigour and performance observed in some orchards Direct infection of the fruit itself does occur to some extent, producing blemishes and cracking on the fruit which is thereby rendered unfit for export and canning purposes, and suitable only for the production of an inferior quality dried product. More marked however, can be the indirect effect of leaf infection on fruit size, which in turn again affects the average yield weight per tree.

Summarizing then, the position is, that all three of the above diseases occur in the western Cape Province and often with disastrous results to our fruit trees and crops. In a number of orchards they are found to occur in the combination of leaf-rust and zinc deficiency, and leaf-rust and manganese deficiency. There is also good reason to believe that all three sometimes occur together in the same orchard of one species of stone fruit.

The control problem before our growers is to what extent sprays containing zinc or manganese compounds, or both, can be used and also timed so as to control any combination of these diseases with a minimum of spray applications. For our climatic conditions under which these diseases occur the answer can only be arrived at experimentally. No detailed results of investigations on the control of any of the above diseases on stone fruits have thus far been reported from South Africa. The results reported below therefore, although in the nature of a preliminary report, should be of some aid in finding a solution of some of the disease control problems of our fruit growers.

Experiments on the Control of Little-leaf.

Preliminary experiments were started in the winter of 1938 on peach and plum trees in an orchard which for several years before had proved highly unprofitable on account of little-leaf. This orchard had received heavy applications of lime over a short period of years previous to 1938, amounting in all according to office records, to 14 tons of lime per acre. Trees in one part of the orchard were taken out in the autumn of 1938 and the land sown to oats. Those left standing and on which spraying tests were carried out were in an exceedingly bad state of little-leaf and die-back.

The treatments given in 1938 were as follows:

(1) Control.

(2) Spray treatment at bud movement only.

(3) Spray treatment at bud movement plus one further application when the trees were almost in full leaf.

The formula used for both the treatment at bud movement and the spring application consisted of commercial zinc sulphate: 10 lbs., and hydrated lime: 5 lbs., per 100 gallons of water.

The results of these treatments are summarized in Table I.

Table .I—Summarizing the Effect on Peach Trees of Spraying with Zinc-lime (10:5:100), 1938.

Number of trees and treatment		Average length of new growth from terminal bud (Inches)	Average weight of leaves and new wood from terminal bud	Average weight of leaves and new wood from 15 inches of leader back of terminal bud.
32	Check	2″ die-back	1·7 grms	6·6 grms
24	Sprayed at bud movement.	1/5″ die-back	4·0 grms	8·5 grms
24	Sprayed at bud movement and again when almost in full leaf	1½″ new growth	6·6 grms	26·1 grms

The unsprayed, as well as those trees sprayed at bud movement showed practically 100 per cent. mottle-leaf early in the summer whereas the trees which had received the additional treatment in the spring showed no more than 5 per cent. mottle-leaf. Towards the end of the season however, the trees of the latter treatment reverted to the mottle-leaf condition but retained their leaves for at least a fortnight longer than the unsprayed trees. In the case of the spring sprayed trees there was generally also a notable increase in the size of the leaves. This is best reflected in the weight of the leaves of the leaders from trees of the various treatments as shown in Table I. The average effect of the disease on the tree is further reflected in the length of the new shoots from the terminal bud of unpruned leaders. It is also shown that only those trees which had had two applications of zinc-lime spray, showed an increase in the length of the leader. The gross impression that the casual observer would have gained of the effect of the various treatments, would have been that the control trees were decidedly worse at the end of the season, that the treatment at bud movement had more or less inhibited the trees from becoming worse, and that the additional spring treatment had benefited the trees beyond recognition.

In 1939 the zinc spray treatments on peach trees were repeated on the 1938 plots, and additional plots were included in which a winter, spring, or summer treatment only, was given. Only one application on the 13th of July was made during the dormant season, the following concentrations of zinc sulphate being used: 50, 20, and 10 lbs. per 100 gallons respectively. The spring treatment was made on the 28th of November when the trees were already in full leaf. A late summer treatment alone or in addition to the spring application, was made on the 23rd of February, 1940. The effect of these various zinc treatments on blossoming as or the 20th October, 1939, is shown in Table II.

Table II.—Showing the Effect of Zinc Spray Treatments on the Blossoming of Peach Trees.

Variety.	Treatment, 1938	Treatment, 1939.	Average number of blossoms per tree
Pucelle	Winter Application Zinc-lime at bud-movement.	Winter Application Zinc only, 10 : 100	357
	Winter Application Zinc-lime at bud-movement.	Winter Application Zinc only, 50 : 100	332
	Winter and spring application of Zinc-lime.	None.	636
	Control.	None.	64
Peregrine.	None.	Winter treatment, Zinc only, 10 : 100	499
	None.	20 : 100	642
	None.	50 : 100	394
	None	Control	90

From the data presented it appears that in the variety Pucelle the greatest beneficial effect on the average number of blossoms per tree in 1939 was derived from the spring treatment in 1938, giving 636 blossoms per tree as against 64 in the controls. Of the winter treatments on the variety Peregrine, the formula 20:100 apparently gave better results than either of the formulae 10:100, or 50:100. Remarkable also is that the formula 50:100 on both of the varieties Pucelle and Peregrine gave lower increases in the average number of blossoms per tree than did the formula 10:100 The effect of the different treatments on mottle-leaf was the same as that observed in 1938. The spring treatment (10:5:100) corrected mottle-leaf practically one hundred per cent. within three weeks after spraying. All the spring treated trees however had reverted to the mottle-leaf condition by the 23rd of February, 1940. On this date a late summer application (10:5:100) was made on trees which had had no previous treatment as well as on trees which had been sprayed in the spring. In either case the summer treatment failed to correct mottle-leaf, the explanation apparently being that all leaf growth had come to a standstill at this stage. One effect of the late summer treatment in addition to the spring treatment, however, was that these trees retained about 10 to 20 per cent. of their leaves for about ten to fourteen days longer than the trees that had only received one spring application.

None of the winter treatments had any striking effect either on little-leaf or on mottle-leaf. The 50:100 formula gave slightly better results than the 10:100 or 20:100 formulae, but not sufficiently so to outlast the effects of the lower concentrations for long.

The unsprayed trees began to shed their leaves before the end of February, 1940, and by the 15th of March they were practically bare of leaves. The winter treated trees not only began to shed their leaves about a fortnight later than those in the control plots but also held their leaves for about two weeks longer. The spring treated trees still retained nearly all their leaves at a stage when the unsprayed trees had shed about 95% of their leaves. That this premature leaf drop in the unsprayed trees was due to a zinc deficiency and not to leaf-rust is evident from the data presented in Table III. It should be explained that the data for the individual treatments were recorded on somewhat different dates and after about 95 per cent. of the leaves in each treatment had already been shed.

The degree of rust infection in the leaves collected from the ground under the unsprayed trees was very mild indeed and decidedly insufficient to have caused premature leaf fall. It will also be noticed that the youngest leaves i.e. those taken from the tips of the leaders showed a higher degree of infection than the older leaves lower down; also that the additional late summer spray had had a marked inhibiting effect on rust infection in the terminal leaves.

Table III.—Showing the Effect of Zinc-Lime Sprays on the Development of Leaf-Rust in the Variety Pucelle.

Treatment.	Source of the leaves examined, and colour of the leaves.	Average Number of rust sori per sq. in. of leaf surface.
Check.	Leaves off the ground; normal autumn yellow.	19·3
	Leaves 1 ft. below tip of leader.	18·1
	Leaves from tip of leader.	88·8
One application of zinc-lime in late spring.	Leaves off the ground; normal autumn yellow	3·4
	Leaves 1 ft. below tip of leader.	7·6
	Leaves from tip of leader.	77·3
Two applications of Zinc-lime: late spring and late summer.	Leaves from the ground; normal autumn. yellow	3·0
	Leaves 1 ft. below tip of leader.	5·4
	Leaves from the tip of leader.	12·0

The gross effect of dormant and spring treatment with zinc sulphate sprays on Pucelle peach trees over a period of two seasons is shown in Figure 4. The results illustrated are so outstandingly remarkable that further comment seems unnecessary.

The results of the 1938 spray treatments on plum trees (varieties Kelsey and Santa Rosa) severely affected with little-leaf and die-back, were less encouraging than those on peach trees. Two applications of zinc-lime (10:5:100) were made, one at bud movement and the other late in the spring. The effect of the treatment was barely noticeable at any time during the summer. As all the plum trees in the orchard were taken out before the winter of 1939, the spray treatment on plum trees had to be continued in another orchard. Only one treatment on Kelsey plums was made during the dormant season of 1939. Two concentrations of zinc sulphate only, 20:100 and 50:100, were used. With the 20:100 formula only a very slight improvement in the condition of the trees was effected. Treatment with the 50:100 formula

Figures 4 (a), (b), (c), and (d).

Zinc deficiency studies on the peach, variety Pucelle. All the photos were taken on the 13th March, 1940.

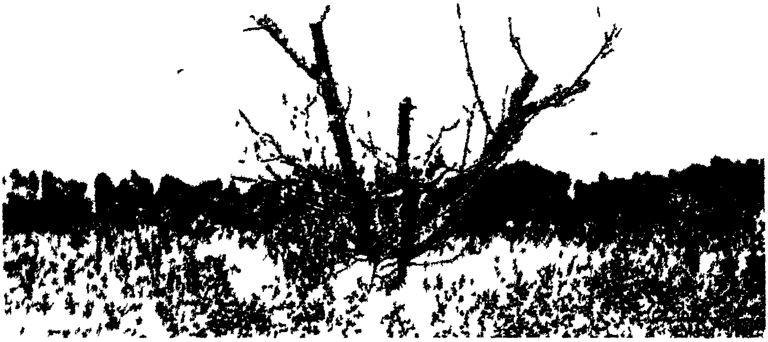

Fig 4 (a)

An unsprayed tree. Less than one percent of the leaves left on the tree. Note the dead leaders on the main limb on the left.

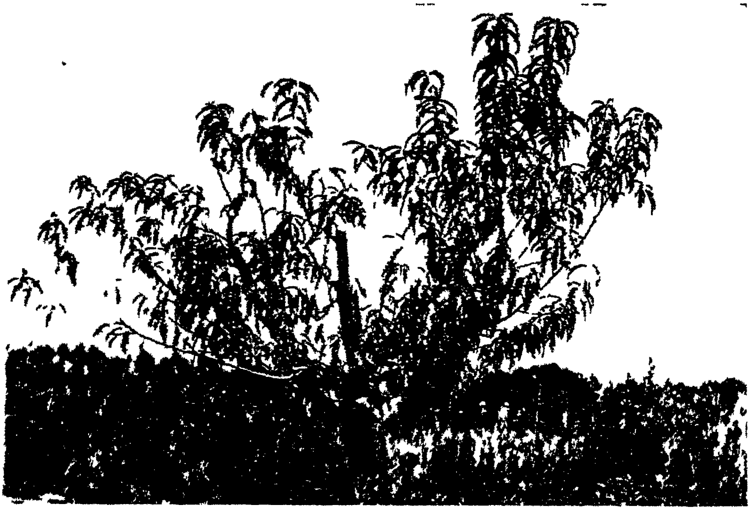

Fig. 4 (b).

A tree sprayed once during the dormant season, 1938, with zinc-lime (10·5·100), and again during the dormant season of 1939 with zinc sulphate only (50 100).

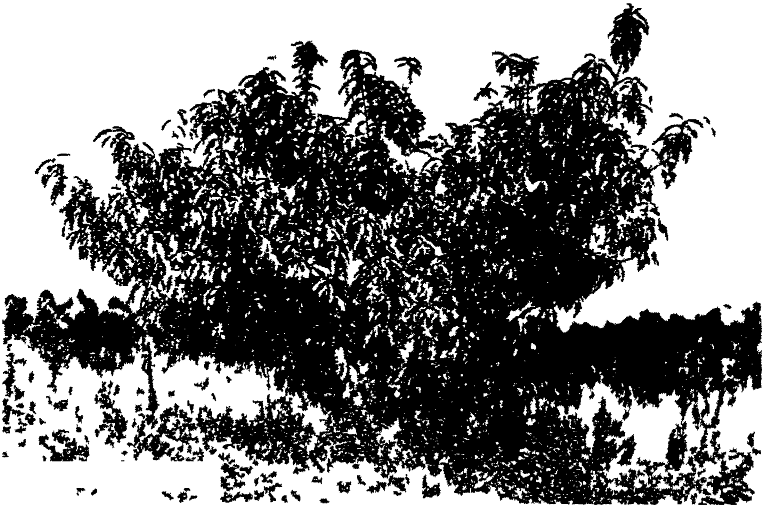

Fig 4 (c)

A tree sprayed twice during 1938 a dormant spray (10 5 100) and a late spring application of same formula A further late spring application was given in 1939 This tree is one of a plot of sixteen trees part of which is seen on the right in the photo (d) below

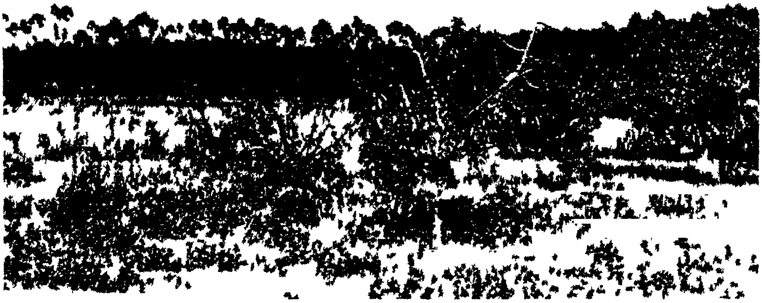

Fig 4 (d)

This photo shows (to the left in the foreground) three of eight unsprayed trees in the control plot adjacent to a plot of sixteen trees sprayed as in (c) above gave better results and there was a striking improvement in the condition of sprayed trees during the early part of the growing season. This improvement, however, became much less marked towards the end of the summer. It is obvious that further tests with zinc sulphate will have to be conducted before definite recommendations can be made as to the best time and formula, or combination of formulae, for the control of zinc deficiency in plum trees.

EXPERIMENTS ON THE CONTROL OF MANGANESE DEFICIENCY AND LEAF-RUST.

During January of 1939 the author had occasion to visit a farm on which all the different species of orchard trees were affected by a mottle-leaf and chlorosis very suggestive of a zinc deficiency. In no instance however was there any evidence of the little-leaf symptoms so characteristic of a zinc deficiency disease. The only other disease symptom accompanying the leaf mottling in this particular instance, was that of a die-back of the leaders and other shoots in Santa Rosa and Kelsey plum trees as also in nectarine trees, as illustrated in Figure 5. Nothing was done about the disease before the winter of 1939 beyond treating a few nectarine peaches and Santa Rosa plum trees with a 10:5:100 zinc-lime spray. This treatment failed to correct the mottle-leaf disease but showed excellent control of leaf-rust on the nectarine. This latter disease was particularly severe in apricot, nectarine, and Santa Rosa plum trees.

Early in December, 1939, tests were made for the deficiency of the following elements: Zinc, manganese, copper, and magnesium. Positive response was obtained only from the manganese treatments. Following upon this, nectarine trees were sprayed on the 31st January, 1940, with the following fungicides: Bordeaux mixture (4:4:100); zinc-lime (10:5:100); permanganate of potash (¼%) plus hydrated lime (½%); manganese sulphate (¼%); and manganese sulphate (1%) plus hydrated lime (1%). As only a very limited quantity of manganese sulphate was available, and no further supply obtainable at the time, only one tree could be done with each of the manganese sulphate treatments. A second application of Bordeaux mixture, zinc-lime, and permanganate of potash was made on the 21st February, 1940, to each half of the number of trees which had received these same treatments respectively on the 31st January.

The results of these treatments are summarized in Table IV.

Table IV.—The Effect of Zinc, Copper and Manganese Sprays on Mottle-Leaf and Leaf-Rust in the Victoria Nectarine.

Treatment	Effect on mottle-leaf.	Average number of rust sori per sq. in. on successive dates.			Estimated percentage of leaves shed.
	On 19/3/40 and 18/4/40	19/3/'40	4/4/'40	18/4/'40	18/4/40
Check	100 per cent. mottled and chlorotic.	79·0	212·5	149·1	Per cent. 95
Potassium Permanganate-lime: one application.	100 per cent. recovery, dark green.	4·0	40·5	84·5	10—25
Same: two applications	100 per cent. recovery, dark green.	10·1	9·5	27·3	10—25
Zinc - lime: one application.	100 per cent. mottled and chlorotic.	0·4	5·2	10·0	15—25
Same: two applications.	100 per cent. mottled and chlorotic.	7·7	7·0	6·4	15—25
Bordeaux mixture: one application	100 per cent. mottled slightly less chlorotic.	0·3	6·4	2·1	10—20
Bordeaux mixture: two applications.	100 per cent. mottled slightly less chlorotic.	2·5	1·0	1·1	10—20

Each of the manganese treatments, whether as permanganate of potash, manganese sulphate, or manganese sulphate plus lime, corrected mottle-leaf within 14 days after application and restored a deep bluish-green colour to the leaves. This deep green colour in the leaves of the manganese treatments persisted until the leaves were shed. Likewise leaves on twigs, both in the plum (Santa Rosa and Sultan) and nectarine, dipped in either permanganate of potash, or manganese sulphate and lime, on the 7th December, 1939, retained the same intense green colour all through the season until they were shed over four months later. Here it should be added that equally good results were obtained on citrus trees by spraying with manganese compounds.

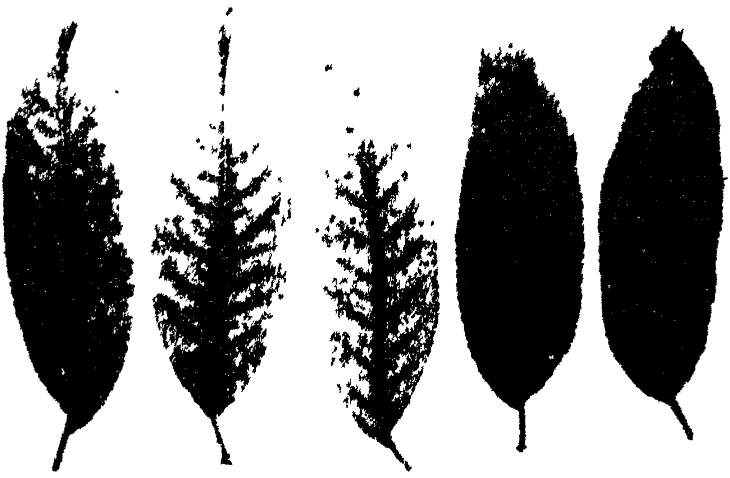

Fig. 6.—Leaves off trees sprayed for the control of both leaf-rust and manganese deficiency. From left to right, respectively: control; Bordeaux mixture (two applications); zinc-lime (two applications); permanganate of potash-lime (two applications); permanganate of potash-lime (one application).

The effect of the various treatments on leaf-rust is self evident from Table IV and is further illustrated in Figure 6. The permanganate of potash treatments were somewhat less effective than either the zinc-lime or Bordeaux mixture applications. For practical purposes of leaf-rust control there was nothing to choose between the zinc-lime and Bordeaux mixture sprays. In all the spray treatments the leaves were retained on the trees for at least three weeks longer than in the case of the unsprayed trees. It is therefore concluded that trees severely affected with leaf-rust in the late summer and autumn lose their leaves at least 3 to 4 weeks earlier than is normal.

SUMMARY.

The three diseases of stone fruits in the western Cape Province primarily responsible for a decline in tree vigour, low crop yields, and the loss of trees are leaf-rust, "little-leaf," and "mottle-leaf," the latter two being caused by a deficiency of zinc and of manganese respectively.

It has been experimentally shown that for the control of zinc deficiency in the peach a late spring treatment with zinc-lime (10:5:100) is far superior to dormant sprays (10:100; 20:100; or 50:100) of zinc sulphate only. On plum trees a dormant spray was found to be superior to a spring application.

Manganese deficiency is recorded for a large number of plant species including fruit trees, ornamentals, and vegetables. Rapid and lasting control of manganese deficiency mottle-leaf was effected by spraying with manganese-containing compounds.

For the control of leaf-rust in nectarine trees late in the summer, zinc-lime sprays (10:5:100) have proved to be as effective as Bordeaux mixture (4:4:100). Spraying with permanganate of potash (¼%) plus hydrated lime (½%) was slightly less effective than applications of zinc-lime or Bordeaux mixture.

In conclusion the author wishes to extend grateful acknowledgments to the Chairman and to Mr. G. Dicey of the Cape Orchard Company, and to Mr. J. W. Mushet, M.P., and his manager, for placing their orchards at the disposal of the Western Province Fruit Research Station and for all possible assistance rendered during the course of these investigations.

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TRANSPIRATION OF LARGE KARROO BUSHES

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During the last 8 years different formations of the South African flora were examined as to their transpiration, and a number of surprising results were obtained when comparing transpiration of different associations per unit fresh matter or surface and calculating these values to the absolute weight of leaves. In comparing the results from a grass veld with those from a forest, it is found that the transpiration per unit fresh matter or surface of the grass veld is very large, even in a dry climate, whilst that from trees in the Drakensberg calculated on the same units is much smaller, perhaps only one-sixth of the former. It is only when we consider the whole formation that we realise that the forest transpires considerably more water than the grass veld. As the water loss of the soil is well within the given rainfall, and allowances for " opslag " or undergrowth are unlimited, the problem is not an economic one.

When similar formations, for instance trees on mountain slopes in different rainfall areas, are investigated, some interesting data are obtained. On the dry slopes in the Karroo one may find trees with thin leaves, as well as on the wet densely wooded slopes of the Drakensberg range. In both formations we also find a number of sclerophyllous species. How can all these different types live in such close proximity?

If a tufted grass veld in the dry region of South Africa is taken, the various species show differences in their transpiration, but on the whole, under the same edaphic and meteorological conditions, these differences are not very large. If, however, a dense forest is investigated where tall trees throughout the day have the benefit of the sun, whilst low bushes only do so occasionally, or get "Sonnenflecken" as it is appropriately called, the differences are large, even if the shade plants are exposed to full sunlight. This applies not only to dense forest as e.g. on the Drakensberg, but to the open tree and bush formation on the hills of Pretoria or in the Karroo. Not that in the latter cases there are many shade plants, but plants with very different leaves are found which transpire under the same exterior conditions with various intensity. And yet when the associations are taken as a whole it is found that not only does the forest on the Drakensberg transpire more than the .open formation at Pretoria per unit soil, and the latter more than the Karroo formation, but the corresponding trees per unit fresh matter and surface have a higher water loss on the Drakensberg than on the Pretoria hills, and these again a higher loss than in the Karroo. With grasses this is not so. Very similar values are for instance obtained for the same species in Bechuanaland and at the Pretoria University. With trees, however, the same species seldom occurs in different associations, only related species.

When the various tree associations are investigated more closely, the first striking difference is in the variety of the size of the trees and of their espacement, and it is not the difference in transpiration per unit fresh matter, which accounts for the different water loss per unit soil, but above all, the espacement and then the size of the trees. This may appear to be obvious, but in their general application these factors are often underestimated. The small Karroo bushes like *Pentzia* or *Phymaspermum* cannot grow nearer together, because under favourable conditions their transpiration is large and there would be insufficient water to draw upon if they were closer. Their most effective expedient for reducing transpiration is dormancy during the dry months, but this does not assist photosynthesis which has to be done when external conditions are favourable.

When the transpiration of associations of South African trees was investigated, it was found that precipitation was far in excess of the water loss. Running off was mostly reduced by a dense undergrowth which itself used some of the surplus water for growth. It is possible that not quite the same statement may be made in connection with grasses in the dry parts of South Africa. Even Karroo bushes do not always survive long lasting droughts, but we seldom find that indigenous trees die.

What is the reason for this? In the first place it is more than likely that the root system of the trees is extensive compared with their aerial parts and that it penetrates very deeply into the soil. Yet, even small Karroo bushes have far extending roots, and may die. There must therefore be other reasons. On the Drakensberg where the trees were investigated during a drought and on clear days in the rainy season, it was found that most trees were able to regulate their water loss according to the available supply. During the drought, transpiration was small when compared with the water loss in the rainy season per unit fresh matter. How does the large bush of the broken veld react under similar conditions?

Since October, 1938, an investigation was made at Fauresmith using the torsion balance of Hartmann and Braun. The trees under investigation grow mostly on the east and north west slope of a kopje that has not been grazed for 13 years. Except for *Olea verrucosa* and *Rhus lancea* there are no large trees, but just large bushes, mostly with sclerophyllous or soft leaves: e.g. *Rhus erosa*, *Burchellii* and *lancea*; *Royena decidua* and *microphylla*, *Tarchonanthus minor*, *Chilianthus arboreus*, a tiny *Euclea ovata*, and *Rhigozum obovatum*. It was often difficult to make the prints for surface determination with accuracy of species like *Rhigozum* and *Royena microphylla*. Besides these trees, a few scattered species of *Acacia* were found. *Acacia litakunensis* and *A. hebeclada*. A few plants of *Heteromorpha arboreus* occurred on the north slope, *Royena decidua* and *Ehretia rigida* were found everywhere between the sclerophyllous trees.

At the commencement of the investigation, experiments were made at infrequent intervals; later two experiments were undertaken per month involving eight plants tested hourly from an hour before sunrise until after dusk. Thus the time of investigation included summer days with excessive heat, seasons of drought and after rains, winters and periods of prolonged spring drought. The most important species were included in nearly all the experiments, the other species were investigated once a month.

On putting together the data collected, one is impressed by the following facts, viz.: (a), the seasonal variation of the transpiration; (b), the difference between the values of the sclerophyllous bushes and of the soft leaved bushes such as *Heteromorpha*, *Royena decidua* and *Ehretia*. The depression in the transpiration values at noon time is also pronounced; it is generally observed in most species even in winter and after heavy rains. It may occur a little later or earlier, but is always observed.

As regards the order of size of transpiration a glance at the daily values, Table I, shows the large variation. Yet in no other formation were the lowest daily values so low, not only for the whole year, but even in summer alone. The highest daily values, which naturally occur during summer, are low to medium. The lowest value in summer may fall as low as the hibernal lowest value. Three distinct groups of trees may be separated: The sclerophyllous trees with low values, the Acacia species with high daily values and Heteromorpha with very low hibernal and high summer values. The lowest water losses are exhibited by the various species of Rhus, the highest strangely enough by Rhigozum. The highest values for transpiration are in most cases found in March or even April, and only bushes with soft leaves like Heteromorpha, Acacia and Ehretia showed their maximal daily values during December 1938. Bur during December 1939 the same bushes had a much lower transpiration, owing to the lack of rain. There is no doubt that the rainfall is responsible for the maxima of the sclerophyllous trees being as late in the season as April and March. After April the values drop in spite of good soil moisture, probably owing to the temperature being too low, as sunlight in May is only about 10% weaker than in summer. It has been noted before that the South African vegetation, in its metabolic functions, is much more dependent on adequate soil moisture, a factor not so important in Europe. Grasses show the maximum transpiration in September to October, small Karroo bushes, although depending on the rain, not later than November. It may be emphasized that at the time of maximum transpiration the stomata function at their best, which is surprising as generally stomata of hard leaves are little movable at that time of the year. With regard to Ehretia and *Royena decidua* they behave as is expected of deciduous leaves, only their daily maximum occurs slightly later in the summer than with other species.

TABLE I.

KARROO BUSHES: DAILY WATER LOSS.

(Water loss in grammes per gram fresh matter.)

	Lowest daily value.	Highest daily value.	Lowest daily summer value.
Olea verrucosa	1·16	6·46	2·77
Royena decidua	2·07	8·43	2·74
Royena microphylla	2·08	10·27	5·17
Rhus Burchellii	1·15	5·50	1·67
Rhus erosa	0·63	5·27	1·09
Chilianthus arboreus	1·33	5·99	1·41
Ehretia rigida	2·26	11·19	2·57
Rhigozum obovatum	2·68	12·86	4·12
Acacia hebeclada	3·65	10·98	
Acacia litakunensis	0·72	11·65	7·16
Tarchonanthus minor	0·80	6·99	2·26
Rhus lancea	0·79	4·97	0·79
Euclea ovata	1·34	6·76	1·34
Heteromorpha arborescens	0·55	11·13	3·27

It is clear that the transpiration of the large bush of the karroid area neither follows increasing light and temperature nor the inverse saturation deficit, but is entirely dependent on soil moisture. In the morning from sunrise to about 9 a.m. there is a parallelism between the other external conditions and transpiration, and again at sunset the decrease of light is followed by the decrease of transpiration. But during most of the day such a co-ordination even in wet weather does not take place.

The question how the low summer values are obtained has still to be answered. It may be recalled here that small Karroo bush shows dormancy of whole plants or at least of branches between April and October, but in the real summer such dormancy is not observed. The trees or large bushes may show this dormancy at any time, regardless of season, depending only on soil moisture. It may happen that in a dry December, *Rhus lancea* may stop transpiring as early as 3 p.m., close the stomata, and hardly show cuticular transpiration. On the whole many more closed stomata were recorded than in any other formation so far investigated.

It is the daily transpiration values that are the most important from the ecological and practical point of view. Again, as at other localities investigated, there are trees which transpire considerably more than others, but in no case are the highest values as high as those of trees on the Pretoria hills or on the Drakensberg.

The following table gives the amplitude of the highest hourly values per 1 gm. fresh matter, as well as the average hourly value in grams.

TABLE II.

KARROO BUSHES: HOURLY WATER LOSS IN GRAMMES, PER GRAM FRESH MATTER.

Plant.	Amplitude of highest hourly values.	Average hourly value.
Acacia hebeclada	0·49—1·70	0·52
Acacia litakunensis	0·28—1·80	0·56
Chilianthus arboreus	0·26—1·09	0·25
Ehretia rigida	0·58—1·72	0·44
Euclea ovata	0·18—1·69	0·28
Heteromorpha arborescens ...	0·19—1·92	0·49
Olea verrucosa	0·28—1·59	0·32
Rhigozum obovatum	0·51—1·81	0·45
Rhus Burchellii	0·29—1·38	0·26
Rhus lancea	0·11—1·21	0·19
Rhus erosa	0·15—0·90	0·23
Royena decidua	0·36—1·24	0·43
Royena microphylla	0·44—1·46	0·47
Tarchonanthus minor	0·17—1·05	0·27

There is no doubt that these trees are capable of losing large quantities of water. The large transpiration values, however, occur only when the soil contains much water which is seldom the case. The species of Rhus are the trees with the smallest transpiration power, on the other hand there is not much difference in the highest values between sclerophyllous trees like Olea or soft leaved trees like Acacia. It is only when the average hourly value per 1 gm. of fresh matter is considered that definite groups can be formed. The species of Acacia have the highest average values, over 0·5 gm.; then the soft leaved or deciduous trees follow with values between 0·4 to 0·5 gm.; then the sclerophyllous trees having hourly values between 0·19 to 0·32 gm. If these latter values are compared with those of other tree formations on the Pretoria hills or on the Drakensberg, it will be seen that the average values are of the order of size of the conifers, but the highest hourly values are much higher. The species of Acacia correspond to those on Klapperkop (Pretoria). The soft leaved trees have similar values to corresponding trees on Klapperkop. but again the highest hourly values at Fauresmith are considerably higher. It must however, not be overlooked that the maximum hourly values for Fauresmith trees may be exceedingly low in winter and especially in times of drought. Summing up these facts it means: that the large bushes at Fauresmith have a high transpiration power when the water supply is good, but this seldom actually occurs. Thus the average hourly transpiration is on the whole lower than that of corresponding trees in a less arid climate. Very low hourly average or low maximum hourly values are found in summer as well as in winter, the summer values during drought can be lower than winter values (e.g. *Chilianthus*). Only in winter it may happen that the highest hourly values correspond to noon time; at other seasons such values occur early in the morning or after 3 p m. In former investigations it has been pointed out that trees have smaller transpiration values per unit fresh matter than grass or even small bush. Thus this large bush formation in the Karroo is a formation which uses little water.

It has already been emphasized that the highest values are found in the rainy season. It follows therefore that there is not necessarily a spring maximum for transpiration. On the contrary, the highest daily water loss may be as late as April or May. Only for deciduous trees like *Royena decidua* do we find a maximum early in the season. Most other trees have their highest daily water loss after February. It is noteworthy that the stomata even of the evergreen trees are much more mobile at the end of the season than those of the small Karroo plants or of trees in other climates.

When it is asked how the low daily water losses in times of drought are controlled, it is interesting to note that the plants apparently use two methods for checking losses, (a) they may have a few quite good transpiration values with stomata fairly wide open, but this is followed by checking transpiration nearly or completely by closing the stomata; or (b) the transpiration value scarcely exceeds the values of cuticular transpiration the whole day, few stomata being open. Even if the stomata afford an effective control they are not the only control. Ehretia and Heteromorpha were found early in the morning or in the evening with widely open stomata and yet no transpiration could be recorded. During the very early morning external factors e.g. too low temperature might be responsible, but this does not appear to be the case in the late afternoon. Heteromorpha in winter shows a very small transpiration although light and temperature may be adequate and the stomata function well. In Olea at times, a sticky substance was found which may act as preventive against excessive transpiration, similar to a substance in Schinus and the creosote tree of the American desert.

These observations indicate that each tree formation has its own peculiarities, even if the general trend of transpiration is governed by laws which can be widely applied.

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THE INFLUENCE OF NITRATE NUTRITION ON THE ALKALOID CONTENT OF *LUPINUS LUTEUS* L.* (1)

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With 2 Text-Figures.

Read July, 1940.

INTRODUCTION.

The alkaloids, being nitrogenous substances, nitrogen must play some part in the synthesis of these compounds by the plant, and a study of the influence of nitrogen nutrition on the alkaloid content of the plant may therefore be of considerable value in the investigation of the physiological significance of the alkaloids. Several investigators have already paid attention to this problem. Vogel and Weeber (1922), for instance, investigated the influence of the root nodule producing inoculation substances, "Nitragin" and "Azotogen," as well as the influence of ammonium and nitrate nitrogen on the alkaloid content of the lupin. They have found that both the percentual and absolute alkaloid content were higher in plants treated with the inoculation substances. Nitrate nutrition by nodule bacteria produced a high plant mass, much protein and a high alkaloid content. Between the nitrogen content and the alkaloid content there consequently appeared to be a very close relationship. When the plants, however, received nitrogen in the form of ammonium and nitrate salts, seed was obtained which was relatively poor in alkaloids.

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* (1) This research forms part of a more extensive investigation on the physiological significance of the alkaloids of *Lupinus luteus*, which was carried out by me under the guidance of Prof. K. Wetzel at the "Institut für Landwirtschaftliche Botanik" of the University of Berlin, and at the "Kaiser Wilhelm-Institut für Züchtzungsforschung," Müncheberg/Mark. Owing to the international situation the investigation could unfortunately not be completed. I herewith want to acknowledge my great indebtedness to Prof. Wetzel for the many facilities and useful suggestions I received from him during my study in Germany.

Gerlach and Seidel (1929) could not confirm this last observation of Vogel and Weeber. They are of the opinion that nitrogen nutrition has no significant influence on the alkaloid content of the lupin seed. From their data a small increase in the alkaloid content as a result of nitrogen nutrition is, however, clear. Iwanoff and his co-workers (Iwanoff and Lawrowa 1930/31 and Iwanoff and Smirnova 1932) regard the alkaloids as superfluous excreta, which owe their origin to the fact that the plant transforms injurious dissimilation products into harmless compounds. From their point of view the alkaloids are therefore nitrogenous products of the regressive metabolism, which, when once formed, can no longer serve as nutrients to the plant. In their investigations they have found that, when the lupin is cultured under different conditions of vegetation, and at different latitudes, there always existed a definite relationship between the other nitrogenous compounds and the alkaloids. A high nitrogen and a high protein content were associated with a high alkaloid content. Under field conditions the nitrogen content, as well as the alkaloid content, depended upon the nodule development on the roots, and when no nodules were formed as for instance under unfavourable soil conditions, then both depended upon the amount of absorbable nitrogenous substances in the soil; in other words, when the possibilities for nitrogen nutrition changed or remained constant, the nitrogen content and the alkaloid content of the plant accordingly changed or remained constant.

The present research was undertaken to throw more light on this problem. In order to carry out the experiments under carefully controlled conditions of nutrition, the water culture method was applied. The research was done on *Lupinus luteus* L. This plant contains two alkaloids, viz. Spartein, $C_{15}H_{26}N_2$, a colourless liquid with a boiling point of 326°C, and Lupinin, $C_{10}H_{19}NO$, a solid which melts at 69°C.

THE PRELIMINARY EXPERIMENT.

Mevius (1927), and especially Schander (1938 a and b and 1939) made valuable contributions in connection with the growth of *Lupinus luteus* in sand and water culture. Schander states: " The lupin is very sensitive to copper. Distilled water obtained from the usual copper apparatus and consequently containing copper, is therefore unsuitable for water culture experiments. The best results are obtained with water distilled from a glass apparatus. The lupin is, furthermore, very sensitive to the hydrogen-ion concentration of the culture solution. For the young plant the reaction-optimum is at pH 4·8—5·0. Both at a higher and at a lower pH-value the plants become chlorotic. The reaction-span, where no chlorosis occurs, is narrower when the salt concentration in the culture solution is high than when it is low. The optimum salt concentration is that of 3 millimol per litre."

In such solutions containing the necessary nutrients a good development of *Lupinus luteus* was obtained. The plants had a strong and healthy root system and a fresh-green leaf colour. As soon as the flower buds, however, appeared the growth was suddenly checked and the plants died. This phenomenon must be ascribed to the fact that the plant requires another pH-optimum from this stage. The reaction-optimum of the older plant is at about pH 6·75; a value which is considerably more alkaline than that for the young plant. This transition in the pH-optimum could not hitherto be made without injuring the plants and *Lupinus luteus* could not be grown in water culture from the seedling stage to the ripe stage. I therefore decided to carry out the experiments on young plants only.

In the preliminary experiment the following served as initial solution:

TABLE 1.

The initial Culture Solution for the preliminary Experiment.

Nutrient Salt.	Concentration (Millimol/Litre)
KH_2PO_4	0·75
$Ca(NO_3)_2{\cdot}4H_2O$	1·2
KNO_3	0·2
$MgSO_4{\cdot}7H_2O$	0.·75
$FeSO_4{\cdot}7H_2O$	0·1
A—Z-Solution (Hoagland)	1cc./Litre

In order to obtain solutions with lower nitrate concentrations, all or part of the nitrates of K and Ca in this initial solution were substituted by the sulphates and phosphates of these elements, while higher nitrate concentrations were obtained by substituting part of the KH_2PO_4 and $MgSO_4 \cdot 7H_2O$ by KNO_3 and $Mg(NO_3)_2 \cdot 6H_2O$ respectively. In making these alterations care was taken to ensure that the total salt concentration was kept constant and that the ratios [K] : [Ca] : [Mg] : [Fe] and [SO_4] : [PO_4] were he same as in the initial solution.

In this way five solutions were obtained with the following variations in the nitrate concentrations:

TABLE 2.

Nitrate Concentrations used in the preliminary Experiment.

Series No.	[NO_3] in Milli-Ion-Weight per Litre.
1	0
2	1·4
3 (Init.Sol.)	2·6
4	3·1
5	3·75

The ions Na and Cl, having evidently no significant effect on the growth of the lupin, the pH-value of all the solutions was adjusted at the optimum (pH 4·8—5·0) by the addition of NaOH or HCl. The preliminary experiment was conducted as follows: Lupin seed was sterilized (to avoid root nodule development) by treating it with a 1% bromine solution for half an hour. The seed was then left overnight in distilled water to swell. The next morning well imbibed seed was selected and sown in fine river sand containing no nutrients. A few days after the plants appeared above the surface, they were carefully taken out of the sand, and after the removal of all sand particles from the roots, transferred to the culture solutions contained in glass pots of 2½ litre capacity darkened by covering them on the outside with a layer of dark paper and a layer of cardboard and provided with lids consisting of thick, paraffined cardboard discs, containing 20 holes each. The plants were held in position in the holes by cotton wool. During the growth period the pH of the solutions was repeatedly determined and when it differed too much from the optimum-value, the solutions were changed. The height of the solution in the flasks was kept constant by the addition of distilled water. The plants of all the series showed good growth. The root development was normal and the aerial parts had a fresh-green colour. In only a few cases nodule development was observed on the roots. These plants were immediately removed.

A month after the plants had been subjected to water culture the experiment was terminated. Most plants of each series then had 10 or 11 leaves. External differences between plants of the different series could not be observed. Even the plants grown without nitrates were not inferior to the others in development.

From this preliminary experiment it is clear that differences in nitrate concentration were too small to produce marked variations in the development of the young plants and that greater differences were required. The cotyledons of the lupin seed contain so much reserve material that even the plants, grown in the solution without nitrates, showed no signs of nitrogen exhaustion.

THE MAIN EXPERIMENT.

For this experiment the total salt concentration was 9· millimol per litre. Only four nitrate series were used, the initial solution (Series 4) having the highest nitrate concentration, which was decreased in the other three series by substituting chlorides of K and Ca for the whole or part of the nitrates. The four series were as follows:—

TABLE 3.

The Culture Solutions used in the Main Experiment.

Salt	Series 1. Millimol/L.	Series 2. Millimol/L.	Series 3. Millimol/L.	Series 4. Millimol/L.
KH_2PO_4	2·25	2·25	2·25	2·25
$Ca(NO_3)_2 \cdot 4H_2O$	0	1·2	2·4	3·6
$CaCl_2 \cdot 6H_2O$	3·6	2·4	1·2	0
KNO_3	0	0·2	0·4	0·6
KCl	0·6	0·4	0·2	0
$MgSO_4 \cdot 7H_2O$	2·25	2·25	2·25	2·25
$FeSO_4 \cdot 7H_2O$	0·3	0·3	0·3	0·3
A—Z Solution (Hoagland)	1cc./L.	1cc./L.	1cc./L.	1cc./L.

The pH of these solutions were again adjusted at the value 4·8—5·0.

The experiment was made with the bitter lupin. Uniform seed material, being unavailable as a pure line, the offspring of a single plant was used. The material was externally quite homogeneous and consequently no significant individual differences were to be expected. The rest of the experiment was conducted in the same way as in the previous case, except that from the second week after the plants were transferred to water culture, the solutions were well aired for two hours every day by means of a tube system connected to an air pump. This considerably enhanced the growth, particularly of the root system.

The roots of the plants were occasionally examined for nodule development. No nodules were observed.

The experiment was again terminated after a month. At this stage the plants of the different series showed marked differences in general development. Though no obvious signs of nitrogen hunger could be detected in series 1, the nitrogenous reserves of the cotyledons not being exhausted, these plants showed a distinct retardation of growth in comparison with the other series.

ANALYTICAL METHODS AND RESULTS.

After removal from the culture solutions, the roots were thoroughly rinsed with distilled water, then dried between blotting paper, and the fresh weights of the different series were determined immediately. The material was subsequently well dried at 60°C and the dry weights were determined. These data are given in Table 4 and clearly indicate the differences in development between the different series.

TABLE 4.

Variation of the plant Weight (expressed in Grams per 100 Plants) with the Nitrate Concentration in the Culture Solution (expressed in Milli-Ion-Weight per Litre).

Nitrate Concentration	0	2.6	5.2	7.8
Fresh Weight	255.1	323.4	341.7	368.9
Air-dry Weight	25.2	27.2	29·6	33.1
Absolute Dry Weight	23.5	25.6	27.9	31.3

After drying, the material was ground to a fine powder with as little loss as possible, and stored in glass bottles for chemical analysis.

The alkaloids were determined by a half-micro method developed by K. Meyer at the "Kaiser Wilhelm-Institut für Züchtungsforschung," Müncheberg/Mark. This method has not yet been published, but Mr. Meyer kindly gave me his permission to apply it. The following is a short summary of the procedure: The fine material is treated with NaOH to liberate the alkaloids, which are then removed by repeatedly shaking with an ether-chloroform-mixture (3:1) and decanting The ether-chloroform-solution is then repeatedly extracted with HCl (0.3%) in the separating funnel. In this hydrochloric acid extract the alkaloids are precipitated with silicomolybdic acid. The precipitate is filtered off, washed, and when treated with a reduction agent, a blue colour is produced. The extinction co-efficient of the colour is determined in the photometer. Meyer developed this method for *Lupinus albus* and *Lupinus angustifolius*. In these species only one alkaloid, viz. lupanin, occurs, whereas *Lupinus luteus* contains two alkaloids, spartein and lupinin, as already stated. Nottbohm and Mayer (1935) have however found that in the 9 cases of *Lupinus luteus* investigated by them, spartein and lupinin occur in a fairly constant ratio, viz. 1 : 1·7. My own unpublished data in this connection confirm their observation. It was therefore decided to use a solution, containing spartein and lupinin in the ratio 1 : 1 7, as a standard.

For every determination 0·300 grams of the air-dry material was used. Simultaneously with the alkaloid determination the absolute dry weight was determined in a sample of 0·500 grams of the same material by drying at 102°C for four hours. The percentage data are expressed on this absolute dry base. All results were checked by double determinations. The values obtained are given in Table 5.

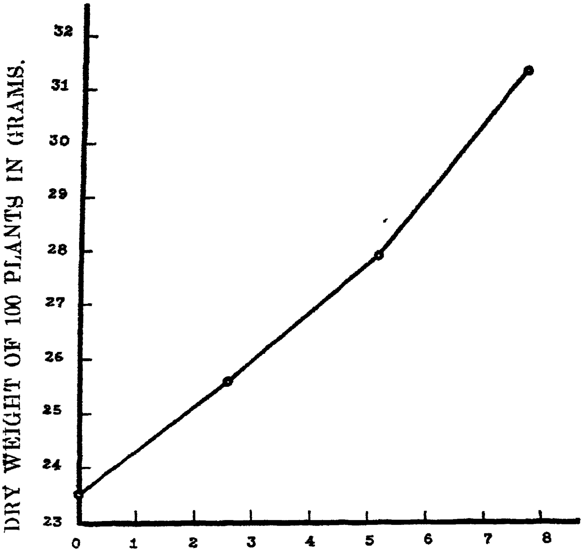
TABLE 5.

Variation of the Alkaloid Content with the Nitrate Concentration in the Culture Solution.

[NO_3] Milli-Ion Weight/L.	% Alkaloids	Alkaloids in m.grams per 100 Plants.
0	0·790	185·7
2·6	0·815	208·6
5·2	0·822	229·4
7·8	0·826	258·5

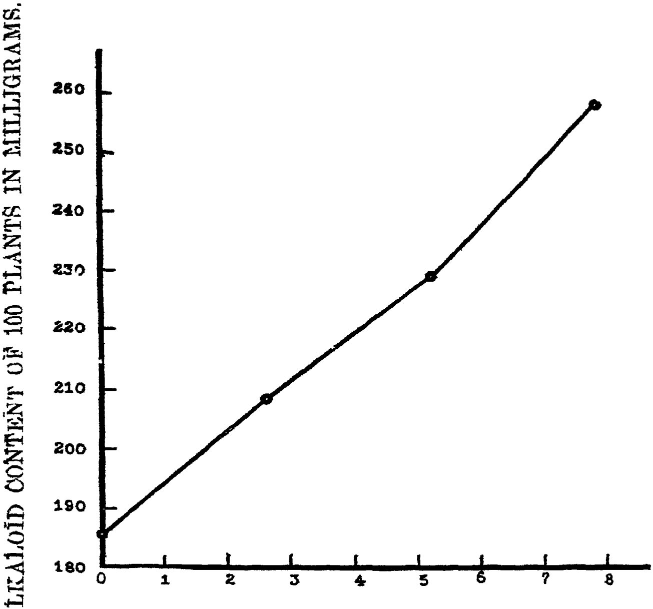
CONCLUSIONS.

From the above data it is clear that the nitrate concentration of the nutrient solution has a marked effect on the dry weight, as well as on the absolute alkaloid content. A high nitrate concentration produces a high dry weight and a high



Nitrate Concentration in Milli-Ion-Weights per Litre.

Fig. 1. Variation of the dry weight of 100 plants with the Nitrate Concentration in the Culture Solution.



Nitrate Concentration in Milli-Ion-Weights per Litre.

Fig. 2. Variation of the absolute Alkaloid content of 100 plants with the Nitrate concentration in the Culture Solution.

absolute alkaloid content (Tables 4 and 5). The curves in Figures 1 and 2, having nearly the same general trend, it is clear that the extra amount of dry weight produced by increased nitrate nutrition is associated with a corresponding extra amount of alkaloids. The dry weight and absolute alkaloid content are therefore affected to the same extent by nitrate nutrition and the nitrate concentration has consequently no significant effect on the percentual alkaloid content (Table 5). Between the production of dry mass and alkaloid synthesis there obviously exists a very close relationship. The nitrate concentration apparently primarily affects the plant mass and, as a result of this, only secondarily the alkaloid content. The influence of the nitrate nutrition on the alkaloid content can therefore evidently not be considered as being specific or direct. It is possible that other ions, which also affect the plant mass favourably, e.g. potassium, may have the same influence as the nitrate-ion on the alkaloid content. Klinkowski and Pfeil (1938) concluded that potassium fertilizers caused a decrease in the alkaloid content of the lupin. All their data do not, however, confirm this conclusion, and more carefully controlled experiments may probably give other results.

SUMMARY.

1. In a preliminary experiment the observations of Schander (1938 a and b) were confirmed, viz. that a good development of young plants of *Lupinus luteus* can be achieved in culture solutions with a total salt concentration of 3 millimol per litre at pH 4.8—5.0.

2. In solutions with such salt concentrations, differences in the nitrate concentration that have a marked influence on the plant development, could not, however, be effected.

3. In the next experiment solutions with a total salt concentration of 9 millimol per litre were consequently used, and four different nitrate series were applied.

4. From this last experiment it was clear that nitrate nutrition has no significant effect on the percentual alkaloid content of *Lupinus luteus*. On the dry weight and absolute alkaloid content it has, however, a marked influence. An increased nitrate nutrition produces an extra amount of dry weight and simultaneously a

corresponding extra amount of alkaloids is synthesised. The effect of nitrate nutrition on the alkaloid content can evidently not be regarded as specific or direct.

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A CONTRIBUTION TO THE CONTROL OF *STOEBE VULGARIS* (SLANGBOS)

BY

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Read July, 1940.

Introduction.

Owing to the abundance and the rapid increase of *Stoebe vulgaris* in the Transvaal, methods of eradication which could be readily and economically applied on an extensive scale have become necessary. The species occurs most abundantly on disturbed sites such as old fallow lands, overgrazed veld, roads and paths and on moist sites.

Methods of Eradication.

The treatments found to be most effective were: (i) Poisoning with a 5% solution of sodium chlorate in previously burnt and unburnt plots; (ii) Removal by means of mattocks to a depth of about 6 inches. In both cases, results obtained by Cohen (1940) were confirmed in this experiment. Each of the above treatments was carried out in 4 plots measuring 1/12 of an acre each.

Sodium Chlorate Treatment:—A 5% solution of sodium chlorate (i.e. ½ lb. to 1 gallon of water) was sprayed over the plants. A success of about 95% was obtained in the first operation. In two out of four plots treated in this way, the grass was burned off 6 weeks before the poisoning was done and the young branches were sprayed. This method is preferable to that of spraying the old branches as the plants are smaller and more vigorous; and consequently a smaller amount of sodium chlorate is necessary. The grasses surrounding the plants of *Stoebe* were also found to suffer less, as the spray could be concentrated on the small bushes. Cohen (1940) reports good results with sodium chlorate solutions of 1¼% and 2½%. In all the plots treated with sodium chlorate, the grass recovery was fairly rapid and the veld was considerably improved within 3 seasons.

Seedlings are often very numerous and in some cases it may be necessary to repeat the spraying treatment after a certain number of years. In the meantime an attempt should be made to prevent the young plants from setting seeds. For this purpose, mowing, pulling, burning or other treatments may be applied. The great drawback in connection with this method is the high cost of sodium chlorate and the amount of labour involved.

MATTOCKING:—In 4 plots of the above mentioned size, all the plants were removed by means of mattocks to a depth of 4-6 inches. Few or none of the original plants were found to shoot again from the ground where the clearing was done carefully. The ground cover occupied by large plants in infested veld is considerable, and the grass cover was greatly improved within the first season after clearing. In this case also, the seedlings of *Stoebe* would have to be dealt with and the young plants should be prevented from seeding as far as possible. If labour could be obtained reasonably cheaply, this method of eradication would prove to be much cheaper than sodium chlorate poisoning.

PLOUGHING:—It was shown in certain experiments at the Botanical Research Station, Frankenwald, that annual ploughing had a detrimental effect ('T' block experiments). In cases, however, where lands were allowed to go fallow, plants rapidly increased and in some places became very abundant within 3 years ('M' block experiments).

CONCLUSIONS.

1. *Stoebe vulgaris* may be successfully eradicated by mattocking the plants out to a depth of about 6 inches. In good grazing veld, the expense will be justified by the improvement of the veld shortly after clearing is done.

2. *Stoebe* could be successfully killed by means of sodium chlorate but the expense involved does not justify the carrying out of this treatment on an extensive scale. Large quantities of water are required for large scale operations.

3. Intensive ploughing will destroy *Stoebe* but it tends to increase on lands once they are left fallow for any length of time.

Frankenwald. 20/5/40.

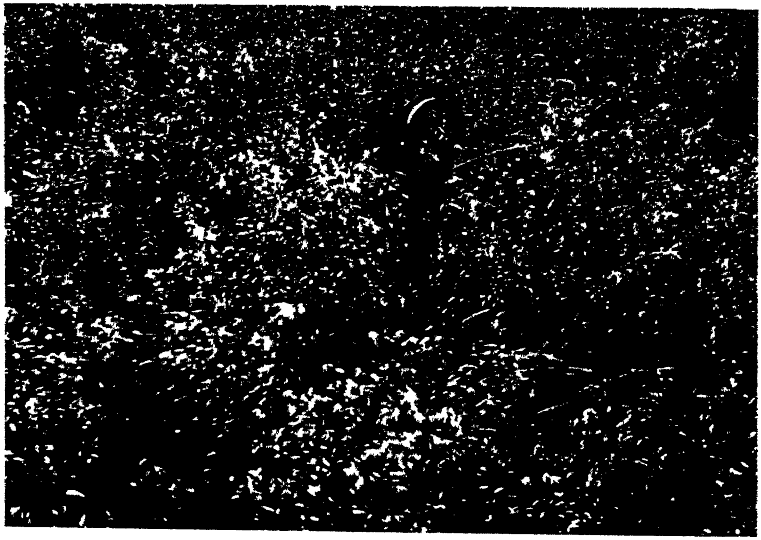
Stoebe very abundant in veld previously disturbed The veld was burned in September 1939, and the plants shown sent up new shoots during the Summer.

Frankenwald, Block U.3, Plot 1 20/5/40.

Stoebe very abundant in a heavily grazed plot. Monocymbium abundant and tall in the background on the left and on the right in plots where Stoebe was sprayed with sodium chlorate solution in December, 1937.

Frankenwald, Block U.3, Plot 4. 20/5/40.

The remains of a large stoebe plant sprayed with a 5 per cent. solution of sodium chlorate in December, 1937. Grasses are rapidly encroaching on to bare ground surrounded by *Eragrostis gummiflua* and *Monocymbium cereciiforme.*



Frankenwald, Block U.3, Plot 3. 20/5/40.

Recovery of *Monocymbium cereciiforme* in a plot where all the Stoebe plants were mattocked out in December, 1937.

ACKNOWLEDGMENTS:—My thanks are due to Dr. John Phillips, Professor of Botany in the University of the Witwatersrand, Johannesburg, under whose guidance this work has been carried out.

NOTE: A detailed description of these experiments will be published later.

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A DECADE OF CITRUS RESEARCH IN SOUTHERN RHODESIA

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Presented July, 1940.

ABSTRACT.

The importance of research to Agriculture, and in particular to fruit culture, is widely recognised to-day but it is only in comparatively recent years that it has gained full recognition and even so one wonders whether the fundamental importance of research to the Citrus Industry is always fully appreciated.

The World production of Citrus has increased steadily during the past decade. This has given rise to increasing competition which has brought home to growers very forcibly the need for improvement in quality and reduction in the cost of production. More attention appears to have been devoted to the former than the latter. The reason for this is that reduction in the cost of production is dependent to a very large degree on securing a higher average yield per tree and this involves research into a very wide range of problems.

A small Citrus Experimental Station was established at Mazoe in April 1931 by the British South Africa Company in the interests of its Citrus Estates. Improvement in both the quality and quantity of the fruit produced has been the foremost task of this Station and the results of the work carried out have been made available to growers throughout the Colony.

Considerable modifications of the cultural methods have resulted from some of the investigations. The furrow system of irrigation has largely been superseded by the basin system, the growth of a cover crop in the Groves during the rains has been abandoned and the preparation of synthetic manure or compost is part of the routine. The importance of soil reclamation, where erosion had taken place, was established

and the comparatively sudden falling off in the trees in certain areas was traced to depletion, over a long period, of the available nitrogen reserves in the soil despite the annual dressings of fertiliser at much the accepted rates. A relatively sharply defined low limit for the available nitrogen content in the soil, under local conditions, was determined.

An Experimental Plot and Nursery was started at Mazoe in 1931 and an Introduction Garden was established. Amongst the problems being studied are stock and scion relationships and the improvement of the principal varieties of Citrus grown by bud selection. This work is all long range and it is as yet too early for definite results.

Complete analyses of the soil from all parts of the Company's Estates have been made and differential fertiliser treatment is given according to the needs revealed. The nature of the fertilisers required by the trees under local conditions has been determined as well as the best method of application and the correct time of application. The importance of nitrogen and phosphorus has been established.

The development of " hard fruit " coupled with the falling off of trees in certain areas showed signs of developing into a serious problem at Mazoe but fortunately it was solved by tracing the trouble to a deficiency or unavailability of boron. Applications of borax to the soil gave remarkable results in controlling the malady within the short space of about twelve months. The effect of soil reclamation, a revised fertiliser programme and control of the " hard fruit " problem in a block of 2,321 trees was that by 1939 production was nearly three times as great as in 1936 and the export five and a half times as great.

Considerable work has been carried out on the various insect pest problems and at the moment reasonable control can be achieved except in the case of the Cotton Boll Worm. Fortunately the degree of attack of this pest varies considerably from year to year and during the past ten years only two really serious attacks have been experienced.

The Citrus Thrips is controlled by spraying with Lime Sulphur to which Colloidal Sulphur is added and Red Scale is dealt with by fumigation. The methods employed have been modified from time to time in the light of the work carried out here and elsewhere and the bionomics of the more important pests have been the subject of special investigations.

Plant diseases are fortunately not so prevalent in this Colony as they are in many Citrus growing countries but the four or five of regular occurrence that are more or less troublesome have been closely studied. A very wide range of the problems directly or indirectly associated with the carrying qualities of the fruit are under constant investigation.

The foregoing brief outline indicates how the Experimental Station at Mazoe is endeavouring to assist the Industry in Southern Rhodesia to meet the increasing competition by improvement in quality and reduction in cost of production. One of the results has been that, since 1935, the Estate cost of production at Mazoe has steadily fallen until for the 1939 season it was 55% of that for 1935.

There seem to be three methods, taken singly or in various combinations, of dealing with the position confronting the grower.

1. By a Government subsidy to the Industry either direct or indirect.
2. By orderly marketing.
3. By co-ordinated research.

It is claimed that it is unsound for an Industry to be dependent on a Government subsidy be it direct or indirect. It is contended that even if orderly marketing should be introduced at some future date the only sure foundation on which to build up the Industry is by co-ordinated research. A plea is made for more extensive research work on Citrus problems taking the long view and looking to the future welfare of the Industry as a whole.

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A NEW GENUS OF SOUTH AFRICAN GRAMINEAE

BY

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With five text figures.

Read July, 1940.

In the "Flora Capensis," four species of Diplachne are described, one of which, viz. *D. biflora* Hack., is commented on as follows: "it is rather different from the other species of the genus, and perhaps not a true Diplachne."

During an examination of the available material of Diplachne it was noticed that *D. biflora* Hack. differs remarkably from the other species in possessing reddish 2- to 6-flowered spikelets, lemmas which are dorsally awned from below the apex, a rhachilla which is bearded in the basal half, and a terete grain. That this species should be placed in a separate genus, was confirmed, and I propose the name *Bewsia* in honour of the late Prof. J. W. Bews, Principal of the Natal University College.

It was thought advisable to study the anatomical features of the leaves together with the external morphological characters, and to incorporate these in the descriptions. The methods followed in this respect are essentially similar to those given by me (Goossens 1938) and Miss Fisher (1939), and therefore need not be repeated here.

Bewsia Goossens. Genus novum, Diplachneae Beauv. affine, sed spiculis 2—6-floribus, rufis; rhachillis infra barbatis; lemmatibus dorso infra breviter aristulatis; grano terete differt.

Spiculae rufae, sub-unilaterales, distichae, breviter pedunculatae; rhachilla supra glumas disarticulans, ad basin barbata. *Glumae* persistentes, subaequales, acutae vel mucronato-acuminatae, membranaceae, glabrae, scabrae, 1-nerviae raro 2—3-nerviae. *Lemmata* 2—6, e glumis exserta, membranacea, obtusa vel bidentata, 3-nervia, nerviis lateralibus sub-marginatis, dorso infra breviter aristulata, basi pilosa, scabrida; callus obtusum, dense barbatum. *Paleae*

obtusae, secus carinas breve et dense ciliolatae, basi sparse pilosae. *Ovarium* anguste ellipsoidium, glabrum; styli distincti. terminales; stigmata plumosa. *Caryopsis* terete, lineare-oblonga. *Gramen* perenne, sub-glabrum; culmi erecti, teretes. solidi, simplices, 3-nodi; foliorum vaginae teretes, a basi divisae, glabrae; foliorum laminae lineares, rigidae vel sub-rigidae, sub-convolutae, in gemma convolutae; ligulae membranaceae, breviter ciliolatae; paniculae obovatae vel obovato-oblongae, densae, patulae.

Species unica.

B. biflora (Hack.) Goossens, comb. nov.. *Diplachne biflora* Hack. in Bull. Herb. Boiss. iii. 387, (1895); Stapf in Dyer Fl. Cap. vii. 593, (1897-1900); *Diplachne biflora* var. *Buchanani* Stapf, loc. cit.. (Figs. 1 to 5.)

Vegetative characters: Sub-glabrous perennial; culms tufted on a short oblique rhizome, erect, up to 90 cm. high, terete, simple, rather slender, rough below the nodes and below the inflorescence, 2—3-noded, internodes usually enclosed except the uppermost; shoots rounded; leaves crowded near the base; leaf-sheaths tight, split from the base, rounded, scabrid to smooth, firm, the lowest reduced to mere expanded bladeless scales; ligule 0·5 mm. long, membranous, truncate, ciliolate; blades linear, acuminate, acute, up to 25 cm. long, up to 6 mm. wide, sub-rigid to rigid, erect, rolled in bud, flat or sub-convolute on drying, densely pilose at the base and with scattered hairs higher up, scabrid on both surfaces and along the sides, indistinctly keeled.

Floral characters: Panicle somewhat contracted, ovate to ovate-oblong, 5-22 cm. long; rhachis branched, angular, scabrid. bearing spikelets more or less from the base, with the lowest branches 3-5 cm. long; spikelets up to 10 mm. long, with 2-6 lemmas of which the uppermost is much reduced and usually sterile, with the rhachilla bearded between the first and second lemma and glabrous further up, sub-secund, 2-ranked, shortly but distinctly pediceled; glumes sub-equal to unequal, lanceolate, acute, often shortly mucronate, 4-9 mm. long, scabrid, with the margins and tips sub-hyaline; lemmas up to 4·5 mm. long, entire, obtuse to sub-acute or often minutely bidentate, dorsally shortly awned from below the readily pruinose tips, scabrid, with the lower or the first and second lemmas silky pilose in the lower half; awn scabrid; pales obtuse, shorter than the lemmas, minutely and densely ciliate along the keels, with the pale of the lower lemma sparsely pilose in the lower half, with the pale of

the uppermost lemma obsolete or very much reduced; callus minute, obtuse, densely bearded; anthers up to 1·75 mm. long; grain linear-oblong, terete, 2 mm. long.

Leaf anatomy: Leaf thin; keel sub-distinct or rounded; adaxial surface with flat-topped ridges and furrows, with asperites on the ridges, with motor cells in all furrows; motor cells in groups of 3-5, with the central cell large and more or less as broad as deep and occupying about half of the leaf thickness; abaxial surface sub-undulating, with usually numerous asperites opposite the bundles; abaxial epidermis (seen in surface view) with numerous asperites, with the stomata in 1 row (rarely in 2 rows) between the nerves, with 1-3 files of long cells of which the walls are undulating adjacent to the rows of stomata, with files of long cells and files of short cells (dumb-bell-shaped silicified cells and cork cells) opposite nerves; vascular bundles girdered by stereome strands, consisting of 2-6 primary bundles on either side of the midrib-bundle, and with 1-4 secondary bundles (rarely also a tertiary bundle) between the primary bundles; bundle-sheath double; outer bundle-sheath of primary bundles consisting of arcs of 2-5 more or less oval parenchyma cells with chloroplasts, interrupted by abaxial stereome strand and adaxially by 1-4 colourless parenchyma cells or by stereome, rarely horseshoe-shaped; outer sheath of secondary bundles horseshoe-shaped, consisting of 4-6 parenchyma cells with chloroplasts, interrupted abaxially by stereome; inner sheath consisting of strongly lignified cells arranged in 1 row in secondary bundles and in 2-3 rows in primary bundles; colourless parenchyma absent over midvein, forming strands on either side of midvein; chlorenchyma more or less in 2 radiating rows round vascular bundles, more or less continuous above motor cells except on either side of midvein; stereome well developed, adjacent to all first order bundles and only abaxially to second order bundles; margin obtuse, without sub-marginal stereome.

DISTRIBUTION: The following abbreviations have been used below:—

N.H.P.—National Herbarium, Pretoria.
N.Mus.—Natal Museum
A.Mus.—Albany Museum.
S.A.Mus.—South African Museum.
N.U.C.—Natal University College Herbarium.
P.U.C.—Potchefstroom University College Herbarium.
T.Mus.—Transvaal Museum.

RHODESIA: Macheke, *Eyles* 2005 (*S.A.Mus.*).

TRANSVAAL: Zoutpansberg dist., Elim Mill, *Thomas* 20 (*N.H.P.*); Tzaneen Estate, *Sampson* (8883 in *N.H.P.*). Potgietersrust, Geelhoutkloof, *Galpin* 9175 (*N.H.P.*); Pyramid Estate, *Galpin* 8881 (*N.H.P.*). Lydenburg, Zwagershoek, *Obermeyer* 378 (*T.Mus.*). Barberton, *Matthews* 2 (*N.H.P.*); Nelspruit, *Liebenberg* 2573 (*N.H.P.*). Carolina, Watervalboven, *Burtt Davy* 1407 (*N.H.P.*). Nylstroom, Warmbad, *Pole Evans* and *Smuts* 681 bis (*N.H.P.*). Middelburg, *Schlechter* 4050 (*A.Mus.* and *T.Mus.*). Pretoria, Groenkloof Valley, *Skea* 55 (*N.H.P.*); Irene, *Pole Evans* 375 (*N.H.P.* and *P.U.C.*); Onderstepoort, *Roets* (12440 in *N.H.P.*); Wolwekloof, *Mogg* 15961 (*N.H.P.*); Eloff's Plantation, *MacDonald* (8881 and 8882 in *N.H.P.*); Meintjeskop, *Burtt Davy* (*N.H.P.*); *McClean* 15 (*N.H.P.*); *Gower* 21 and 27 (*A.Mus.*); Fountains Valley, *Skea* 7 (*N.H.P.*); Wonderboom, *Pole Evans* 422 (*N.H.P.*); Sunnyside, *Mogg* 15983 (*N.H.P.*); Waterkloof, *Bews* 269 (*N.U.C.*); Premier Mine *Rogers* (24041 in *T.Mus.*); Pretoria, *Leendertz* (12542 in *T.Mus.*). Marico, *Oberholzer* 106 (*P.U.C.*); *Smuts* 1189 (*N.H.P.*). Rustenburg, Pilansberg, *Pole Evans* 640 (*N.H.P.*). Germiston, *Fenn* (8884 in *N.H.P.*); *Rogers* 12153 (*A.Mus.*). Johannesburg, *Hitchcock* 24142 (*N.H.P.*); *Cohen* 935 (*N.H.P.*); Benoni, *Bradfield* 329a (*N.H.P.*); Modderfontein, *Haagner* (*A.Mus.*). Ventersdorp, Goedgedacht, *Sutton* 542 (*N.H.P.* and *P.U.C.*) and 564 (*N.H.P.*). Potchefstroom, *Stapelberg* (*P.U.C.*); Boschkop, *Louw* 648 (*P.U.C.*).

ORANGE FREE STATE: Heilbron, Makouvlei, *Brandmuller* 121 and 39 bis (*N.H.P.*).

NATAL: Umpumulu, *Buchanan* 282 (*N.Mus.*); Weenen, *Buchanan* (18215 in *N.Mus.*). Zululand, *Jenkens* 7963 (*N.Mus.*); Godwane, *Jenkens* (14021 in *T.Mus.*).

Without precise locality, *Smuts* (*N.H.P.*).

Bewsia as well as Diplachne shows affinity with the *Chlorideae* from which Bewsia differs, however, in that the spikelets are somewhat pediceled and are less distinctly unilaterally arranged on the spike-like racemes of the panicle. I, therefore, feel justified in placing it close to Diplachne which is included under the *Festuceae* by Bews (1929) and other authors.

Although I have not seen *Buchanan* 219 on which Stapf, loc.cit., has based his *Diplachne biflora* var. *Buchanani*, I feel convinced that this plant is not a variety. In fact, I have come to this conclusion by examining specimens which were identified as such by Dr. Stapf. Furthermore, the features given in " Flora Capensis," loc. cit., only have a relative value and allow for a wide interpretation. The only definite character given is the length of the spikelets, viz. 8 mm. long, while both Hackel and Stapf give the length of the spikelets as 5 mm. After a careful study, I found that the spikelets of a single panicle may vary from 5 to 10 mm. in length. It seems clear that the variety, as given in the " Flora Capensis," loc. cit., cannot be maintained, but should be referred to the species of the new genus.

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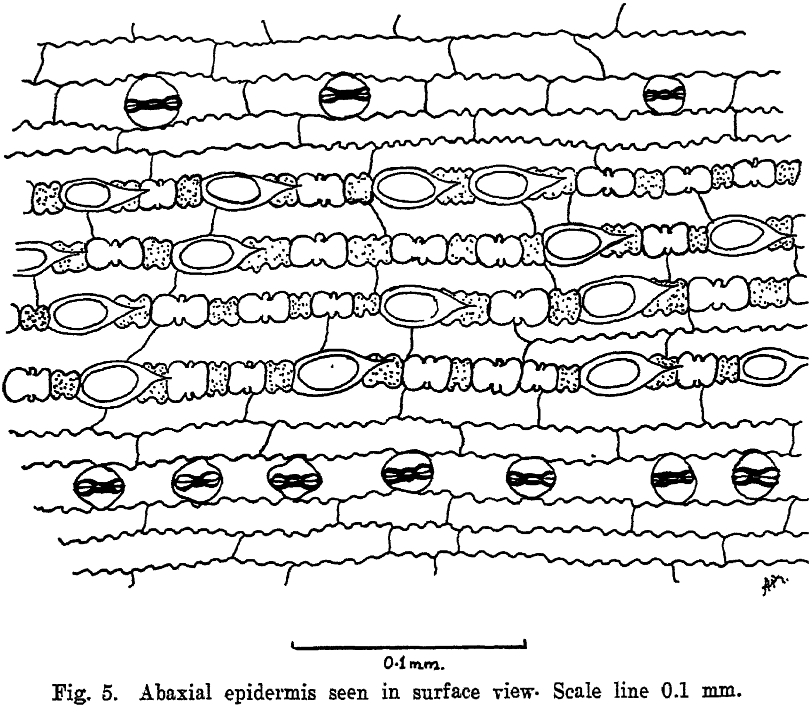

Fig. 5. Abaxial epidermis seen in surface view· Scale line 0.1 mm.

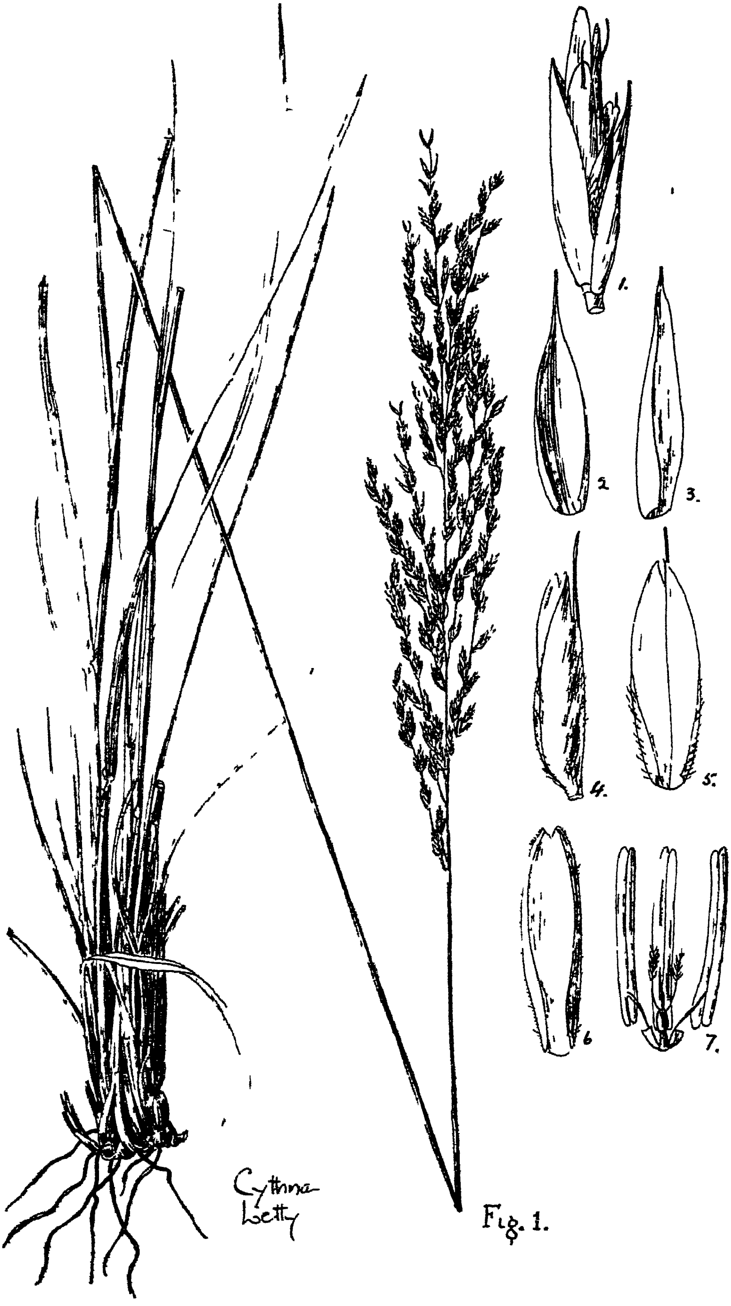

Fig. 1.

Fig. 1. *Bewsia biflora.* Plant natural size. 1. Spikelet; 2. Lower glume; 3. Upper glume; 4.-5. Lemma; 6. Pale; 7. Bisexual floret. (all x 10).

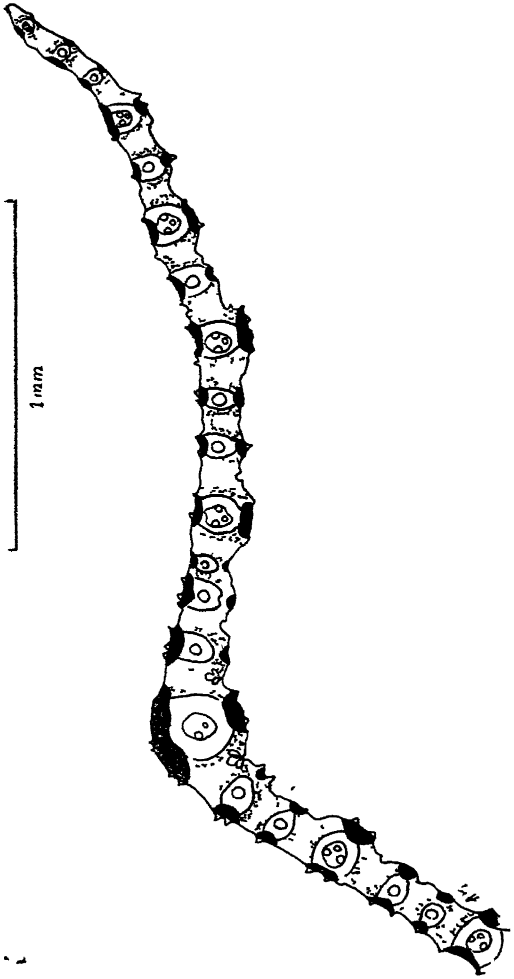

Fig. 2. Transverse section of leaf. Scale line 1 mm.

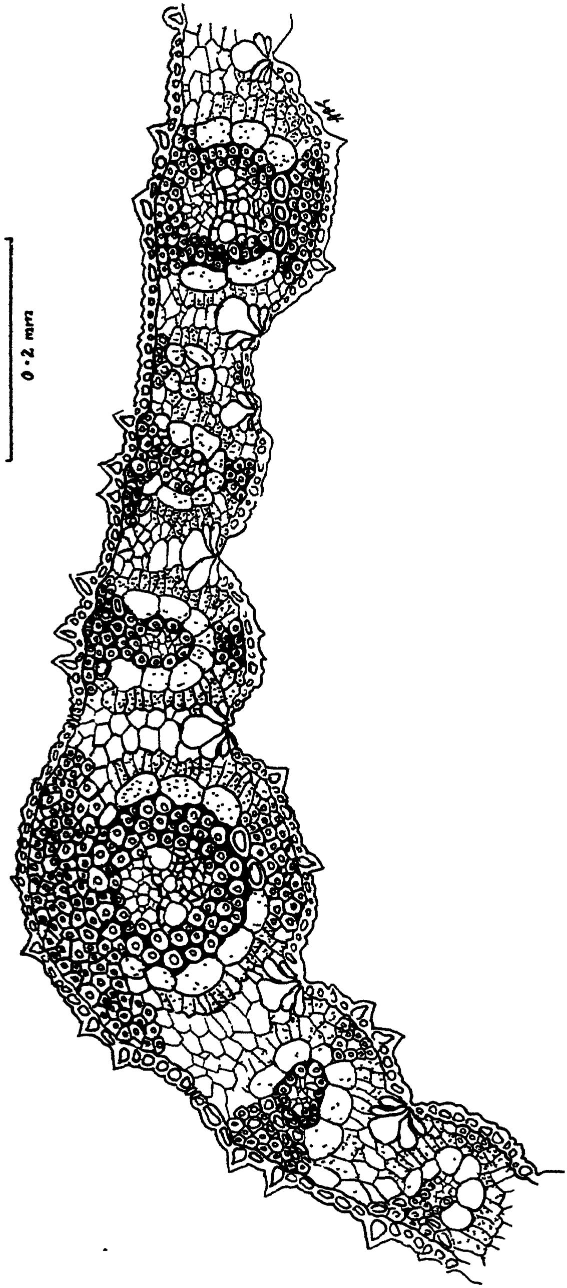

Fig. 3. Transverse section of leaf more highly magnified. Scale line 0.2 mm.

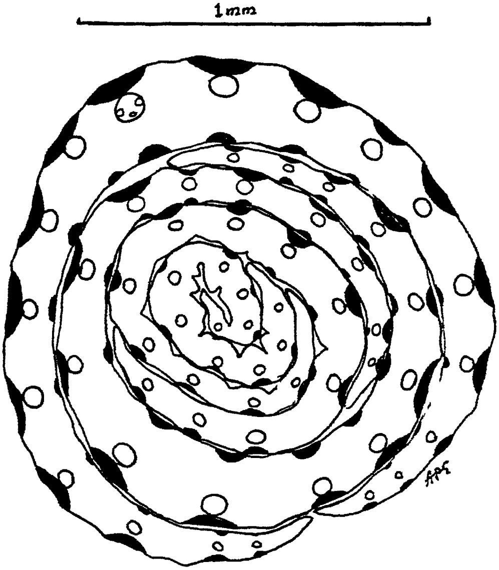

Fig. 4. Transverse section of shoot. Scale line 1 mm.

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CRANIAL ANATOMY OF THE GENUS GERRHOSAURUS

BY
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Presented July, 1940.

The earliest work on the genus Gerrhosaurus was that of Siebenrock (1892); this paper is, however, chiefly an account of the cranial osteology of the Scinks; the other two families were examined chiefly for purposes of comparison. Three views of the skull of *G. nigrolineatus* are figured.

In the classification of Sclater (1899) only three species are given for the genus Gerrhosaurus: *G. validus*, *G. typicus* and *G. flavigularis*. Boulenger (1910) gives a list of all six species of Gerrhosaurus which have been described: *validus*, *flavigularis*, *nigrolineatus*, *auritus*, *typicus* and *grandis*. Hewitt (1910) in a paper which includes a key to the South African species of Gerrhosaurus confirms Tornier's statement that *G. nigrolineatus* and *G. flavigularis* are one and the same species.

Versluys (1898) gives a short description of the middle ear and related parts in Gerrhosaurus. Brock (1935) mentions this genus in her discussion on the temporal bones of lizards, while Broom (1935) figures and describes the entire temporal region of *Gerrhosaurus validus*. Frequent mention is also made of Gerrhosaurus in Camp's "Classification of Lizards" (1923). Apart from these passing references no important work has been done on the genus since the time of Siebenrock.

Material and Technique.

Microtomized sections were made of G. *typicus* and *G. flavigularis*. *G. flavigularis* was collected and fixed by Dr. de Villiers while the specimen of *G. typicus* was museum material originally supplied by the S.A. Museum, Cape Town The fixation of *flavigularis* was excellent, and the same applies to that of *typicus*, except for the epithelium of the mouth cavity, which showed slight signs of maceration. The observations on the glands of the buccal cavity are therefore based on conditions in *G. flavigularis* but most of the other anatomical details refer to *G. typicus*.

Owing to the extreme hardness of adult reptilian skulls the material was decalcified in Ebner for three weeks. In toto staining with Haemalum and counter staining on the slides with Van Gieson's solution yielded very satisfactory results. The illustrations of the skull and nasal capsule were made from graphic reconstructions (squared paper and Panphot-projection method).

A series of sections of a late Gerrhosaurus embryo (species unknown) was very kindly lent by Dr. Brock for comparison with the adult forms.

PRESENT INVESTIGATION.

NASAL REGION: Since the Gerrhosauridae and Lacertidae are supposed to be closely related (they are grouped together under one superfamily, Lacertoidea by Camp (1923)), one would expect the chondocrania of the two families to show close resemblance. This indeed proves to be the case, when the chondocranium of Gerrhosaurus is compared with Gaupp's description and Ziegler's model of that of *Lacerta agilis*. Fig. 3 is a reconstruction of the nasal capsule from the ventral side. The foramen apicale is indicated on the inner side of the two dome-shaped cartilagines cupulares. The ramus medialis of the 1st branch of the trigeminus passes through it. It also allows for the passage of a small bloodvessel (Fig. 4). Both the fenestra dorsalis nasi and the fenestra lateralis nasi are present, and also the foramen for the ramus lateralis nasi innervating the lateral gland. The processus maxillaris anterior and p.m. posterior are both present: the former being fairly short (130μ) and the latter reaching very far back (Fig. 3).

Judging from numerous graphic Panphot reconstructions the taeniae, septum interorbitale, sphenethmoid cartilage, planum supraseptale are practically identical with that of Lacerta.

The organ of Jacobson is encased in a capsule partly bony and partly cartilaginous (Broman 1919). The septomaxillary supports the anterior, dorsal, and part of the lateral sides of the organ. Ventrally it is supported by the cartilaginous zona annularis (Gaupp) which forms a cushion of cartilage (pilzförmiger Wulst) in the centre of the organ. The septum nasi, cartilago paraseptalis and the vomer, all take part in forming the medial skeletal wall. In Gerrho saurus the organ has cartilaginous support posteriorly as well. In cross section this appears as a cartilaginous network, through the meshes of which that part of the olfactory nerve, which innervates the epithelium of the organ of Jacobson, passes. In following the series of sections backwards, the cartilage first appears in the mediodorsal corner of the organ, and gradually replaces the epithelium until the condition shown in Fig. 5 is reached. The plexus is ±340μ thick and forms an adequate supporting wall. In the newly hatched embryo of Gerrhosaurus, referred to above, a procartilaginous stage can be seen quite clearly, showing that this plexus develops fairly late in ontogeny. This would account for the fact that neither Gaupp nor any other worker on the development of the chondocranium of Lacertilia mentions it.

In a series of sections through an adult Lacerta a very similar structure was found, but here the cartilage appeared in the form of a cylinder, with the nerve fibres more or less concentrated in the centre (Fig. 6). In a series through a late embryo of Mabuia indications of a similar structure can also be seen. In this form it appears as two or three slender bars running parallel to the cartilago paraseptalis.

The cartilaginous plexus is continuous with the paraseptals in several places (Fig. 5), and may be regarded as a local development of the cartilago paraseptalis for strengthening the posterior wall of the organ of Jacobson, and particularly for the protection of the nerve fibres innervating the organ. This would seem to indicate that the region posterior to the organ of Jacobson is adapted to withstand stress or pressure of some kind. Adaptations of the paraseptals point to a similar conclusion: the paraseptals are continuous with the solum nasi but are interrupted for some distance immediately behind the plexus cartilaginis paraseptalis. The paraseptals thus consist of an anterior portion continuous with the zona annularis and the plexus, and a posterior portion continuous with the planum antorbitale.

The fact that the connective tissue between the zona annularis and the vomer is very loose indicates the possibility of movement in the front part of the vomer. The moment food is taken into the mouth (usually fairly large insects) the anterior part of the vomer will be pressed upward against the zona annularis and squeeze the fluid out of the lumen of the organ of Jacobson (Broman 1919). The interruption in the paraseptals possibly prevents this pressure from affecting the entire nasal capsule, and makes a greater movability of the anterior division of the paraseptals possible. The function of the plexus cartilaginis paraseptalis is probably to protect the nerves running through it, when the paraseptals and vomers are being moved up and down.

Another peculiarity indicating movement of the vomer is the disappearance of the connective tissue between the bone and the cartilaginous plexus (Fig. 5). The fact also that the anterior divisions of the paraseptals are separated from the septum nasi by very loose connective tissue, and are applied closely to the dorso-median rim of the vomers, seems to support this theory. Further evidence is the following: although most of the glandular areas, described by Fahrenholz (1937) for the oral cavity of Lacertilia, are present in Gerrhosaurus, the one usually found (e.g. Varanus) on the " Vomerpolster " (Fuchs 1908) is entirely replaced by stratified epithelium. Delicate glandular tissue in this area would have made strong pressure impossible (Fig. 5).

THE GLANDS OF THE BUCCAL CAVITY: With the exception of the glandulae vomerales posteriores mentioned above, the only other glands which are absent are those on the upper lip. On the whole the glands are better developed on the lower than on the upper jaw. The terminology of Fahrenholz is used.

The glandulae vomerales anteriores are situated immediately in front of the openings of the organs of Jacobson i.e. in the " primary palate " of Fuchs. They are represented by a median unpaired polystomatic gland.

The glandulae sphenopterygoideae are represented by a large glandular area, consisting of cylindrical epithelium lining the entire orbital groove (" Orbitalmulde " of Fuchs 1908), and choanal grooves (" Choanenspalte " of Fuchs), and continuous with the secretory epithelium of the nasal passages. Each choanal opening is bounded behind by the palatine which is trough-shaped anteriorly with the trough directed downwards; posteriorly it flattens out (Fig. 7b) The hind portion of each choanal groove lies in this trough which is therefore also lined by cylindrical epithelium. The condition of the palatine in Gerrhosaurus appears to be intermediate between that of Lacerta where it is more or less flattened (according to Ziegler's model), and the Scinks where it is very deeply grooved (de Villiers 1939; Kingman 1932)

The glandulae palatinae consist of a longitudinal row of single glands each opening independently, along the

"Innenlippe" (Busch) parallel to the teeth, and reaching from a position opposite the organs of Jacobson to a position opposite the choanal openings (Fig. 7a).

In the angle of the lower jaw a composite gland is situated which corresponds exactly to the glandulae mandibulares which Fahrenholz describes and figures for Lacerta viridis. Compare also Hübner's description of the "Unterzungendrüse" in *Lacerta agilis* (1937). It consists of two parts: a ventral paired portion, whose halves are fused anteriorly, and a paired latero-dorsal part. The former is a polystomatic gland with all the openings located in the fused area, while the lateral portion consists of an aggregate of independently opening single glands.

The secretory cells on the tongue are concentrated in crypts, which resemble isolated glands, but contain undifferentiated epithelial cells as well as secretory cells. The glands on the glottis are similar to those on the tongue.

The glandulae labiales inferiores are represented by a well-developed polystomatic gland reaching to the corner of the mouth on either side.

OSTEOLOGY OF THE SKULL.

The *septomaxillary* is intimately connected with the organ of Jacobson. Anteriorly it forms the bony wall of the organ, the front part of which lies in a hollow in the bone, so that it appears in section as if the organ of Jacobson is entirely surrounded by the septomaxillary. After the appearance of the lumen in the sections, only the dorsal part of the bone remains. There are two backwardly directed processes: a fairly long one closely applied to the centre of the septum nasi on each side, and a short more ventrally directed one.

The connective tissue disappears between the septomaxillary and the solum nasi immediately in front of the organ of Jacobson. Lapage (1928) mentions a similar condition for several Anurans and accepts this as proof that the septomaxillary in Anurans is a cartilage bone. She maintains moreover that the septomaxillary of Reptiles, although apparently a pure membrane bone, may have a cartilaginous basis. No mention is made in any of the literature on the development of Reptiles (e.g. Rice 1920; Hafferl 1921; Brock 1929, 1932) of cartilaginous elements which take part in the formation of the septomaxillary. In developmental series of the Gecko and a snake Leptodeira, kindly lent me by Dr. Brock the septomaxillary was seen to develop as a typical membrane bone in a dense concentration of cells in the cutis. De Beer (1937) comes to the conclusion that the septomaxillary, in Reptiles at any rate, is a pure membrane bone. The disappearance of the connective tissue in Gerrhosaurus may be regarded as another result of the pressure exerted upon the skeletal capsule of the organ of Jacobson.

The *vomer* is paired, meets its fellow in the middle line and articulates only with the premaxillary and the palatine. Laterally it has a process lying between the opening of the organ of Jacobson and the choanal opening. This process disappears beneath the maxilla but does not articulate with it, since the choanal groove separates them completely (Fig. 2). From the discussions on the organ of Jacobson it is evident that the front part of the vomer is loosely attached to the premaxillary, the solum nasi and the septum nasi, but is closely applied to the anterior division of the paraseptal and the plexus cartilaginis paraseptalis The vomer is trough-shaped with the trough facing upward, i.e. in the opposite direction to that of the palatine.

The palatines do not meet in the median line, being separated by the orbital groove. They articulate with the vomers, maxillae and pterygoids. To the outside of the articulation with the pterygoid, each palatine has a posterolateral process which ends freely (Fig. 1). The relations of the palatines to the choanal grooves have already been discussed.

The Nasals: These first appear in section as two bony splints lying vertically on either side of the disappearing unpaired premaxillary in a deep groove formed by the nasal cartilages (Fig. 4). A median splintlike process of the unpaired premaxillary is thus clamped between two similar processes of the nasals. In the embryo the nasals are completely separated by connective tissue, but in the adults of both species they are partially fused in front and completely fused in their posterior halves. The nasal overlies the frontal for a fairly long distance, and appears in section as a process lying in a shallow groove in the frontal.

The two *frontals* show no tendency to fuse in the median line. Each frontal has a ventral process in front of the eye, which extends to the planum antorbitale, and is attached behind this latter to the palatine by means of strong connective tissue (Fig. 7b). It lies partly median to and partly behind the ventral part of the prefrontal, which forms the anterior bony wall of the orbit; thus the frontal also takes part in the formation of this wall. The frontal is bounded by the nasal, prefrontal and parietal, and just meets the postfrontal along the margin of the orbit, so that the parietal takes no part in the formation of the orbital margin.

A limited amount of movement seems possible between the frontals and parietal in the mesokinetic joint (Versluys 1936). Each frontal has a strong postero-lateral process which lies in a groove along the antero-lateral side of the parietal. The process appears diamond-shaped in cross-section, the two inner sides fitting into this parietal groove. The lower, outer side rests on an anterior process of the postfrontal, so that only the outer, upper side appears on the surface (Fig. 8).

The frontal does not form a ledge for the support of the *supraocular scales* along the margin of the orbit as in *Eumeces* (Kingman 1932). The scales merely abutt against the frontal (Figs. 7b and 8). There are eight of these supraocular scales, arranged in two rows of four each. Siebenrock (op.cit.) called the upper row the scutum supraoculare and the lower the scutum supraciliare. They cover the prefrontal II (supraorbital of Siebenrock) completely and also that part of the prefrontal I lying behind the anterior edge of the orbit (Fig. 7a). The scales of the upper row are large and slightly curved, while those of the outer row are small (Figs. 7a and b). *The prefrontal II* (adlacrimal, supraorbital) is a small vestigial bone articulating with the prefrontal in front of the orbit and forming part of the orbital margin. It is completely covered by the first supraocular scale of the upper row, which no doubt accounts for its vestigial character (Fig. 7a).

The *prefrontal* itself lies between the frontal, nasal and maxilla anteriorly and forms a large part of the bony covering of the nasal capsule. Further back it is almost completely covered by the supraocular scales. Immediately in front of the orbit the prefrontal broadens out to form the anterior bony wall of the orbital cavity. Where this ventral part lies against the planum antorbitale, the separating connective tissue disappears (Fig. 7a). Along the anterior margin of the orbit this ventral portion articulates with the lacrimal, but further back it loses this contact, and lies in a medial position to the ductus naso-lacrimalis. At this point the duct runs through a bony canal formed by the lacrimal and maxilla on the outside and the prefrontal on the inside (Fig. 7a). Posteriorly the prefrontal has two processes, one lying on the " Gaumenplatte " of the maxilla beneath the naso-lacrimal duct, and another more dorsally disposed one lying horizontally along the ventral process of the frontal (Fig. 7b).

The Lacrimal: In " The Classification of Lizards " 1923, Camp states that he was unable to find a lacrimal in Gerrhosaurus. Both Siebenrock's illustration of *G. nigrolineatus* (*flavigularis*) (1892) and Broom's figure of *G. validus* (1935) show a very definite lacrimal. In both species which I investigated, the lacrimal is relatively large and forked at the extreme anterior tip. Except for a small anterior part which lies between the prefrontal and the maxilla, the lacrimal forms the antero-ventral edge of the orbit. Since it lies along the outside of the nasolacrimal duct only its upper edge appears behind the vertical part of the maxilla (Fig. 7). A few sections in front of the one shown in this figure, the lower edges of the lacrimal and the postero-ventral process of the prefrontal meet, forming a groove in which the still undivided ductus nasolacrimalis lies. At its extreme posterior tip the lacrimal meets the anterior end of the jugal.

The Jugal: This bone is fairly well-developed in Gerrhosaurus. It consists of a broad horizontal part, and a more slender vertical portion forming the posterior margin of the orbit, and directed backwards at a slight slope. Dorsally it articulates with the downward process of the postorbital by means of very loose connective tissue. This would enable the two bones to slide against each other, and must be taken as an indication that the mesokinetic joint between the frontals and the parietal (Versluys 1936) allows for a certain amount of movement. A small branch of the ramus maxillaris V runs in the horizontal portion of the jugal and sends off branches to the skin through small foramina on the outer surface.

The *temporal region* of lizards has been dealt with very fully by Versluys (1924), Broom (1935) and Brock (1935) Broom concentrated chiefly on the temporal fossae and the postorbital and postfrontal, while Brock gives a comprehensive account of the squamosal-tabular and paraquadrate-squamosal question.

In the posterior temporal region of Lacertilia there are two bony elements: an outer which is fairly large and an inner which is small and vestigial. Gaupp (1894) called the inner element in Lacertilia squamosal because its development corresponded to Parker's definition of the mammalian squamosal, while he applied the term paraquadrate to the outer element. Thyng (1906) showed that Parker's definition was wrong and that Gaupp's reptilian paraquadrate is homologous with the bone in mammals which Parker called squamosal. Gaupp's squamosal is called supratemporal by the Huxley school and tabular by Versluys, Willeston, Broom, Fuchs and Brock. In this paper these two elements will be called simply " outer bone " and " inner bone," so as to avoid continual repetition of the double nomenclature.

The temporal region in Lacertilia shows a tendency towards degeneration, due to the widespread retention in the group of a complete armour of bony scutes over the head (Versluys 1924), although these have disappeared from the body in many cases (Broom 1935). The Gerrhosauridae are fully armoured, and the scutes are especially noticeable over the eyes and temporal region. The upper temporal fossa is lost completely in both species investigated, while the "inner element " is vestigial. Siebenrock (1892) in his illustration of *G. nigrolineatus* (*flavigularis*) indicates two roofing bones in the temporal region immediately behind the eye. He called them the postfrontal I and II, the former being the smaller inner and the latter the larger outer element. Broom in his paper on the temporal region in lizard skulls (1935) examined *G. validus,* and called these two elements the postfrontal and postorbital respectively. According to Broom the temporal regions of Gerrhosauridae and Zonuridae show a close resemblance although they are not at all closely related. In these two families, as opposed to most others, the postfrontal is small, while the postorbital is large and forms the greater part of the temporal roof. The postfrontal articulates with both frontal and parietal but not with the jugal.

Camp, quoting Siebenrock, states that the postorbital is excluded from the orbit, but according to Broom's illustration it does form part of the posterior edge of the orbit. It actually articulates with the jugal in front, and lies along the greater part of the outer edge of the parietal.

The condition in *G. flavigularis* was found to be identical with that given by Broom for *G. validus.* In *G. typicus,* however, no indication of two separate bones could be found, but the single element corresponded in form and position to both postfrontal and postorbital of the other two species

(Fig. 2). In this species the two elements must be fused completely, as it does not seem probable that the postfrontal could have been lost and the postorbital could have replaced it so exactly.

Brock (1935) in a discussion on the homologies of the temporal bones in lizards, birds and mammals, agrees in the main with Thyng (1906), and gives a comprehensive account of the temporal bones in Agama, Mabuia and Gerrhosaurus. She does not, however, figure the latter. She comes to the conclusion that "the outer element" i.e. the paraquadrate squamosal may be regarded as primarily an investing bone of the quadrate head, and the inner element, i.e. the squamosal-tabular, as an investing bone of the posterior wall of the otic capsule, i.e. the occiput." In Gerrhosaurus the "outer bone" is relatively large and lies along the outside of the posterior half of the postorbital (Fig. 2). Its hind end rests on the head of the quadrate but does not fuse with it in any way. The inner element is very small; anteriorly it lies between the lateral process of the parietal and the "outer element," and posteriorly it is wedged in between the parotic process and the head of the quadrate, thus coming to lie on the intercalary, and appearing as an investing bone of this cartilaginous element.

The connective tissue disappears between the parotic process and the "inner bone," the fusion between the two being more or less complete. The connective tissue also disappears between the intercalary and both the "inner bone" and the crista parotica. The tendon attaching the outside of the extrastapedial portion of the columella auris to the intercalary could be seen clearly in these sections (Goodrich 1930 and Versluys 1936). A vestigial ligament could also be seen passing from the extracolumellare to the intercalary, representing the old base of the processus dorsalis (Goodrich 1930).

Naturally the head of the quadrate is not fused with any other element, since it is movable, but is attached to the crista parotica, the "outer bone" and the "inner bone" by means of dense connective tissue. The intercalary is fairly large, and is applied closely to the crista parotica and is even slightly fused with it. The quadrate articulates with the intercalary by means of a definite synovial joint; such a joint between the quadrate head and the "outer element" appears to be a characteristic of burrowing forms (de Villiers 1935 for Acontias). The synovial joint between the cartilaginous quadrate head and the intercalary is, however, typical for all lizards. This would make the jaw articulation of lizards hyostylic, since the intercalary is a hyoid derivative (Versluys 1936).

The surface of the lower articulatory facet of the quadrate does not show the normal reptilian condition given by Versluys. Instead of having a convex quadrate facet which fits into a shallow cavity in the articular, as is the case in most reptiles, Gerrhosaurus approximates more nearly to the pleurodire Chelonian condition, where the articular is knob-like and fits into the concave articulatory surface of the quadrate.

The *parietal* is a single median element. It articulates with the frontals and possesses grooves along the antero-lateral sides in which the posterior processes of the frontals lie. The parietal has four posterior processes: two lateral and two median (Fig. 1). The ventral processes which articulate with the epipterygoids are not well-developed. The lateral processes are directed backward and slightly outward, and articulate along the outer edges with the postorbitals, the " outer bones " and at the extreme posterior tips with the small " inner bones."

The median processes reach back even further than the lateral processes, and are practically horizontal instead of being directed downwards as in most lizards. The lateral and median processes of each side enclose a deep bay between them. Anteriorly the median processes are joined for a short distance and appear in section as a dome-shaped structure, in the ventral groove of which the processus ascendens tecti synotici (Gaupp) lies. The median processes form a deep narrow notch posteriorly, through which protrudes a long ridge formed by the ossified proc. ascendens tecti synotici and the spina of the supraoccipital. This knob-like structure suggests the location of an interparietal (Kingman 1932) but no dermal elements take part in its formation. The anterior tip of the proc. ascendens tecti synotici is enclosed in a canal in the parietal for about 280μ immediately behind the parietal eye. A similar condition has been noted for various lizards by de Villiers (1939) and Haas (1935 and 1936). This would serve to anchor the " occipital segment " of the skull to the " maxillary segment " (Versluys 1924), while movement would still be possible between the two segments.

The position of the parietal eye is indicated on the surface of the parietal by a small, raised, diamond-shaped area, which has a slight depression in the centre but no foramen. The parietal eye is well-developed, possessing the typical Lacertilian structure (cp. Boveri 1925), but no accurate histological details could be made out, as the sections were too thick (24 μ). The eye is completely covered by bone except for a tiny foramen visible in one section only. In a couple of sections it appears as if the organ were covered by an independent bony lid. In *G. flavigularis* this separate bony covering shows very clearly and there is no indication of a foramen.

Camp (1923) states that Gerrhosaurus and Anniella are the only known cases in which the loss of the foramen is not accompanied by the loss of the eye. But since then eyes which are completely covered and yet show no degeneration have been noted for Acontias (de Villiers 1939).

The parietal has no definite ventral process for the articulation of the epipterygoid as is the case in the Scinks and some other families (Versluys 1936). In a cleaned skull of Tiliqua this ventral process was seen to be nearly as long as the epipterygoid itself, the upper end of which leaned against this proces.s In Gerrhosaurus there is only a slight thickening on the ventral surface of the parietal, on the outside of which the tendon of the musculus levator pterygoidei finds attachment. This tendon is exceptionally large and strong and lies against the membranous side wall of the brain cavity. Where the tendon lies against the taenia tecti marginalis, some of its fibres pass along the inside of the cartilaginous bar, but the greater part of the fibres pass along the outside. The tendon is thus closely attached to the taenia tecti marginalis and would serve to brace it against the parietal. Immediately behind this, the upper end of the epipterygoid is also attached to the taenia by means of a tendon. The upper end of the epipterygoid thus rests against and is attached to the taenia tecti marginalis, which in turn finds support from the parietal process by means of the tendon of the musc. levator pterygoidei. There is no contact between the epipterygoid and the prootic.

Although the adult *auditory capsule* is apparently composed of one single element only, definite sutures, which appear as strips of cartilage in the bone can be seen (cp. Haas 1935 and 1936). These, in all probability, lie along the lines of fusion between the component elements. Three definite bony elements can be seen which make up the bony labyrinth. The upper inner part of the labyrinth is continuous with the supra-occipital and apparently part of it. The posterior part including the larger part of the crista parotica is formed by the exoccipital. As the opisthotic usually takes an important part in the formation of the crista (Versluys 1936), it must be completely fused with the exoccipital since no indication of any suture could be seen The remaining and principal portion of the auditory capsule is formed by the prootic. A prolongation of the prootic also takes part in forming the crista parotica anteriorly (Fig. 9).

The foramen ovale is situated between the prootic and the exoccipital, and is bordered by a thin cartilaginous ring (cp. Haas 1935). This ring is of course part of the cartilaginous strip between the two bony elements (Fig. 9). Cartilaginous sutures also remain between the prootic and both basioccipital and basisphenoid.

The foramina of the auditory capsule are similar to those given by Gaupp for *Lacerta agilis*. Siebenrock (1892) states that the 9th and 10th nerves issue from the skull through the same foramen, but enter the skull wall separately inside. The actual condition is shown in Fig. 10. The two foramina are actually separate but the wall of the auditory capsule bulges over at this point, so that both nerves issue between this bulge and the tubercle of the skull base. In a cleaned skull this would appear on the outside as a single foramen in the skull wall.

The relations of the chorda tympani to the columella auris are the same as for Lacerta. The other nerves and bloodvessels in this region also have the normal relations to the columella and related parts in the middle ear (Fig. 9).

Versluys (1898) gives a description of the middle ear and related structures in the family Gerrhosauridae. The tympanic membrane is situated about 1 m.m. below the surface of the skin. The membrane is very delicate and pressed outward by the extracolumellare. It faces completely sideways. The Eustachian tube is very wide resembling that of Uromastix (Versluys 1898). The recessus scalae tympani is very large and the epithelium of the middle ear bulges into it, so that a deep recessus of the middle ear lies over the tuberculum sphenoccipitale (Versluys 1898).

Only three elements can be distinguished in the adult *skull base*: basisphenoid, basioccipital and exoccipitals. The processus cultriformis is completely fused to the basisphenoid and no separate parasphenoid elements can be made out (Siebenrock 1892). The basisphenoid has two postero-laterally directed processes which take part in forming the tuberculum sphenoccipitale (Fig. 9). It appears in section as a small separate bony entity lying at the ventral corner of the skull. The exoccipital takes no part in the formation of the tubercle but a backwardly directed splint of the prootic remains between the exoccipital and the tubercle. The extreme posterior part of the tubercle is formed by this prootic process. The other bones of the skull base and palate are typically Lacertilian and their relations can best be seen in Fig. 2. The vomer and palatine have been discussed elsewhere.

The palatal portion of the *pterygoid* is approximately triangular. The anterior angle articulates with the palatine, the lateral with the transversum and the posterior corner is continued backwards as a process of more or less the same length as the bone itself. It reaches back nearly to the quadrate but is not attached to it in any way. The articulatory surface for the basitrabecular process is situated on the antero-medial side of this process. The meniscal cartilage on the pterygoid is much longer than the facet of the basitrabecular process, thus making a sliding motion possible in the metapterygoid joint (cp. Versluys 1936).

Dorsally the pterygoid has another facet for the articulation of the lower end of the epipterygoid. In front of and continuous with the cartilage of this facet is a fairly long cartilaginous process which lies along the pterygoid but remains separated from it by connective tissue.

In a list of Lacertilians which bear palatal teeth Camp (1923) includes Gerrhosauridae, and Siebenrock (1892) describes six teeth on the pterygoid of *G. nigrolineatus* (*flavigularis*). In a macerated skull of *G. validus* ten teeth were observed. Both *G. flavigularis* and *G. typicus* have teeth on the pterygoid but it was not found possible to count them in the sections.

The *transversum* is forked posteriorly and the two processes clasp the laterally directed portion of the pterygoid, from above and below (Fig. 2).

THE LOWER JAW.

Investigations on the lower jaw yielded nothing of particular interest. The seven bony elements given by

Versluys (1924) are all present. The splenial does not reach as far forwards as it does in Lacerta, and is forked anteriorly, a narrow, upper process lying above the sulcus cartilaginis Meckelii (Fuchs 1931) and a broader and longer process below it. The angular is a very small element lying only on the outer surface of the jaw. It has a foramen for the nervus mylohyoideus (Versluys 1924) The angular does not reach either the splenial or the posterior process of the coronoid. In the region of the fossa prearticularis there is a large foramen in the surangular through which a nerve passes. This may be the foramen auriculo temporalis which lies between the dental and surangular in Physignathus (Fuchs 1931). The processus retroarticularis appears to be made up of both gonial and articular. The surangular is also partly fused with the articular. The foramen for the chorda tympani is definitely situated in the gonial, and not between the gonial and articular.

SUMMARY.

The investigations on the two species of Gerrhosaurus yielded the following points of interest:—

1. The chondocranium is very similar to that of *Lacerta agilis* as described by Gaupp.

2. The paraseptals are interrupted about halfway along their length.

3. Behind the organ of Jacobson and immediately in front of the abovementioned interruption each paraseptal develops a cartilaginous plexus, for which the name *plexus cartilaginis paraseptalis* is suggested. This serves to protect the nerve fibres, innervating the organ of Jacobson from pressure exerted by the vomers in connection with the filling mechanism of the organ of Jacobson. This structure is also present in *Lacerta agilis* and Mabuia.

4. All the glandular areas described by Fahrenholz for the oral cavity of Lacertilia are present except the glandulac vomerales posteriores and the glands of the upper lip.

5. The septomaxillary is a pure membrane bone, and the disappearance of connective tissue between the bone and the solum nasi is a secondary result of stress around the organ of Jacobson.

6. *G. validus* and *G. flavigularis* have two roofing bones in the anterior temporal region: the postfrontal and the postorbital. Both of these take part in forming the orbital

margin. The postorbital is the larger element and forms the greater part of the temporal roof. *G. typicus* has only one element which may be regarded as a fusion product of the two elements present in the other two species.

7. The parietal eye is well-developed, but the foramen is completely closed by a bony covering.

8. There is no definite parietal process for the articulation of the epipterygoid but the head of this structure is attached to the taenia tecti marginalis, which is in turn braced against the parietal by means of the tendon of the musculus levator pterygoidei.

9. Cartilaginous sutures can be seen between the various component elements in the adult auditory capsule.

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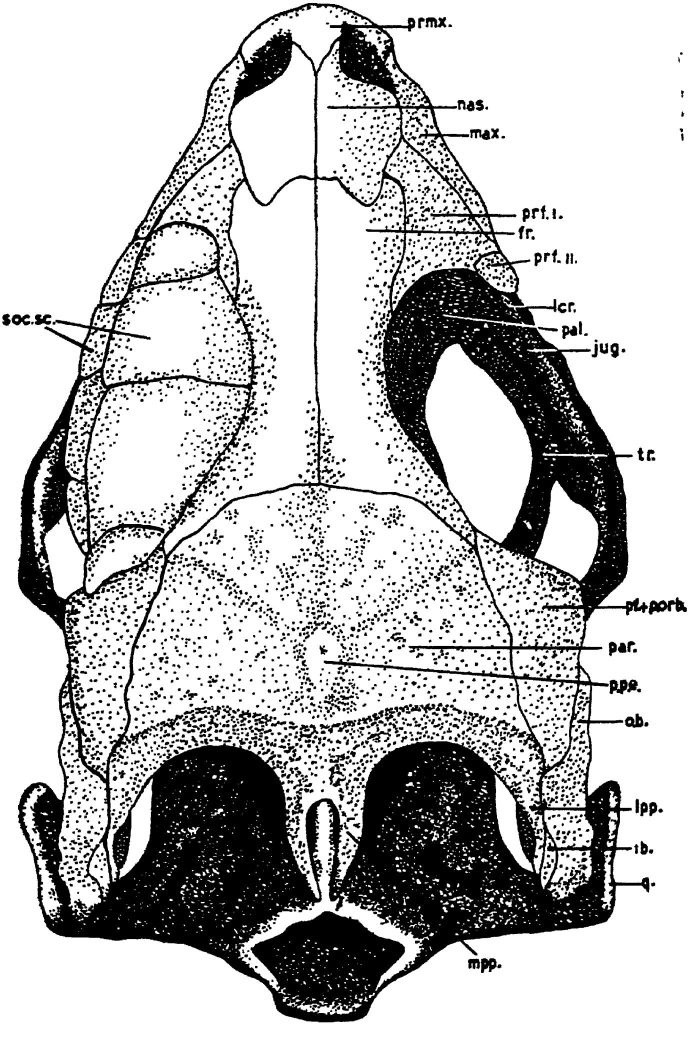

Fig. 1.—Graphic reconstruction of skull—dorsal aspect. fr., frontae; ib., "inner bone"; jug., jugal; lcr., lacrimal; lpp., lateral parietal process; max., maxilla; mpp., medial parietal process, nas., nasal; ob., "outer bone"; pal., palatine; par., parietal; pf.+p.orb., postfrontal+postorbital; ppe., position of parietal eye; prf. I., prefrontal I.; prf. II, prefrontal II; prmx., premaxilla; q., quadrate; soc. sc., supraoccular scales.

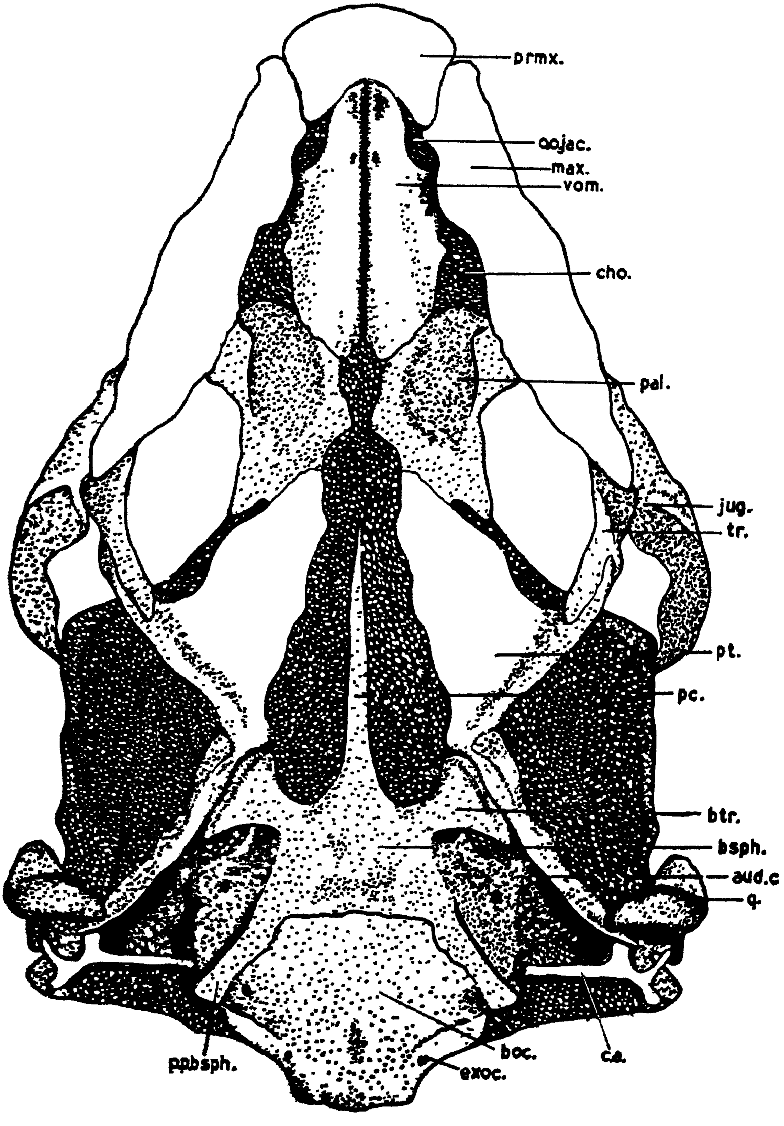

Fig. 2.—Graphic reconstruction of skull—ventral aspect. (Neither maxillary nor pterygoidal teeth were reconstructed). aud.c., auditory capsule; boc., basioccipital; btr., basitrabecular process; bsph., basisphenoid; c.a., columella auris; cho., choanal opening; exoc., exoccipital; o.o.jac., opening of organ of Jacobson; p.c., processus cultriformis; p.p.bsph., processus posterior of basisphenoid; pt., pterygoid; tr., transversum; vom., vomer.

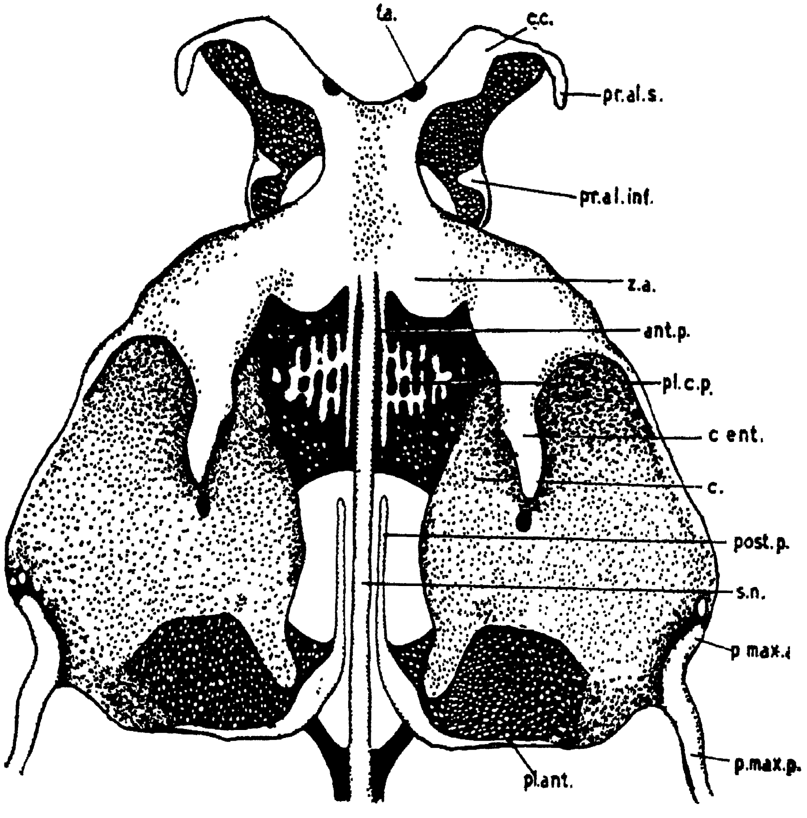

Fig. 3.—Graphic reconstruction of cartilaginous nasal capsule—ventral aspect. ap., anterior paraseptals; c., concha; c.c., cartilago cupularis; c.ent., cartilago entochoanalis; f.a., foramen apicale; f.n.s., fenestra superior nasi; pl. ant., planum antorbitale; pl. c.p., planum cartilaginis paraseptalis; p.max.a., processus maxillaris anterior; p.max.p., processus maxillaris posterior; p.p., posterior paraseptal; pr.al.inf., processus alaris superior; s.n., septum nasi; z.a., zona annularis.

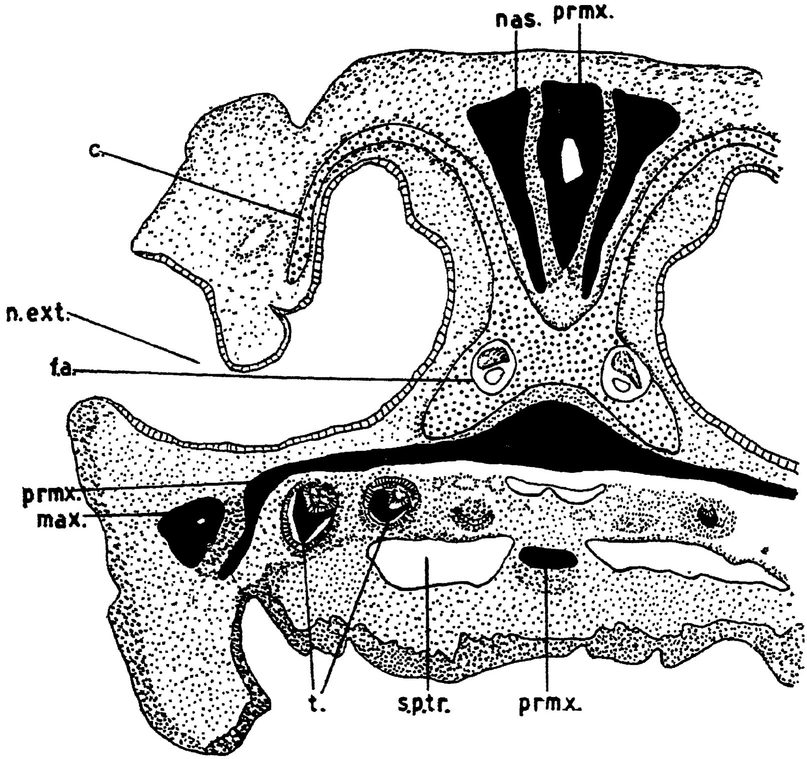

Fig. 4.—Transverse section through nasal region. n. ext., nares externa; s.p.tr., sinus palatinus transversus; t., tooth.

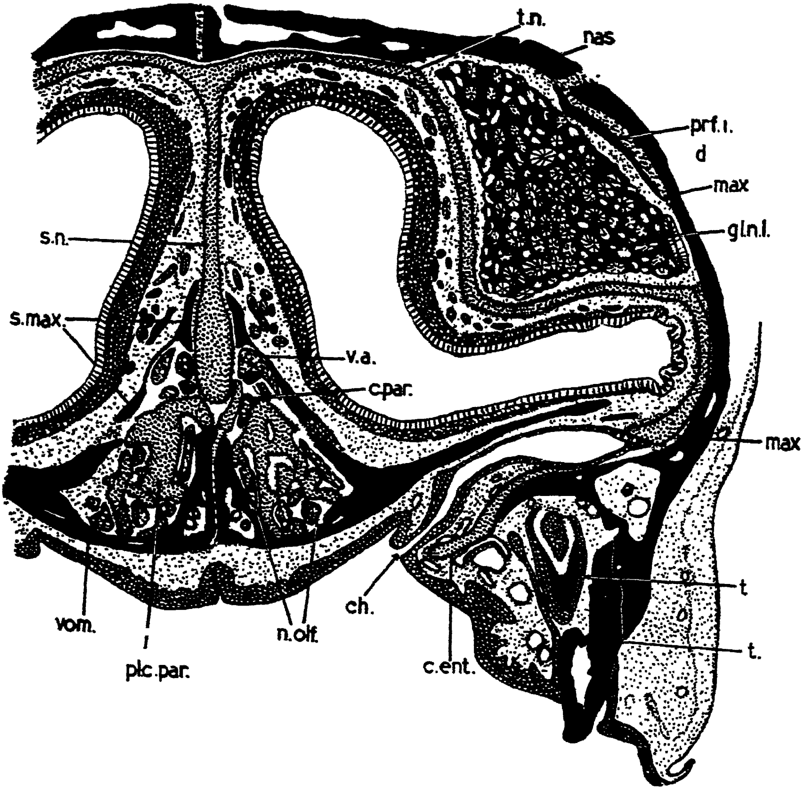

Fig. 5.—Transverse section immediately behind organ of Jacobson (Gerrhosaurus). c. par., cartilago parasaptalis; gl.n.l., glandula nasalis lateralis; n.olf., nervus olfactorius; pl.c.par., plexus cartilaginis paraseptalis; s.max., septomaxillary; t.n., tectum nasi.

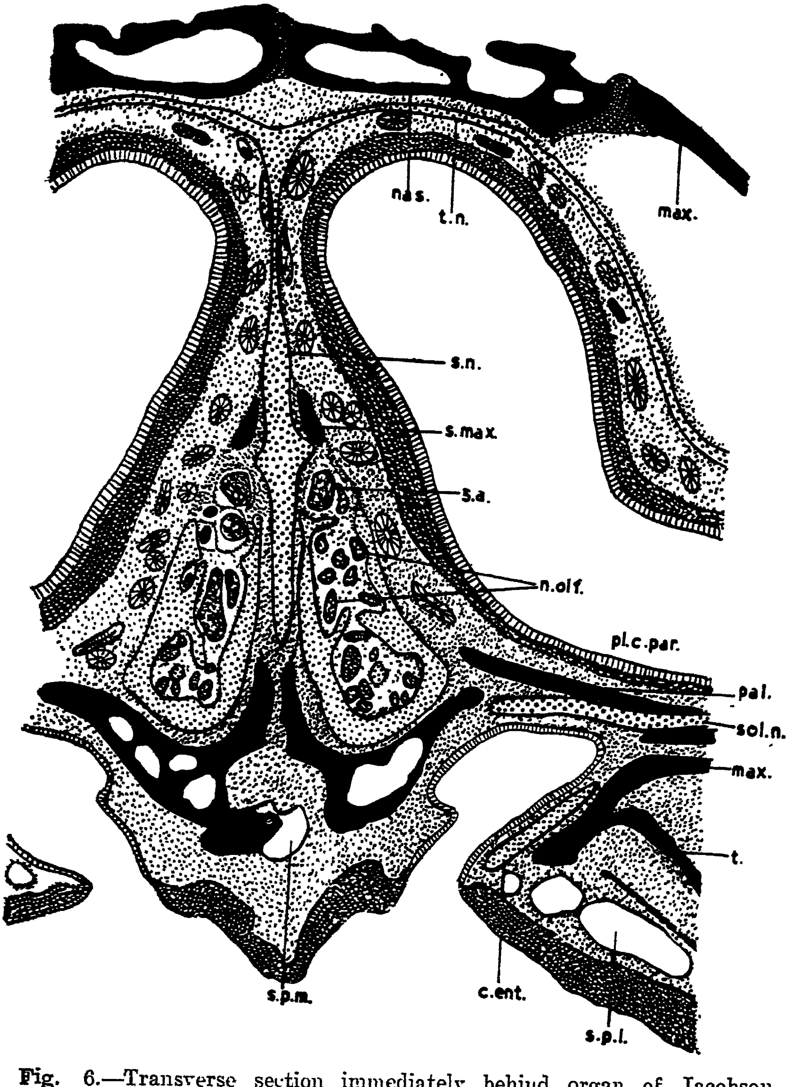

Fig. 6.—Transverse section immediately behind organ of Jacobson (Lacerta). s.p.l., senus palatinus lateralis; s.p.m., sinus palatinus medius; sol.n., solum nasi.

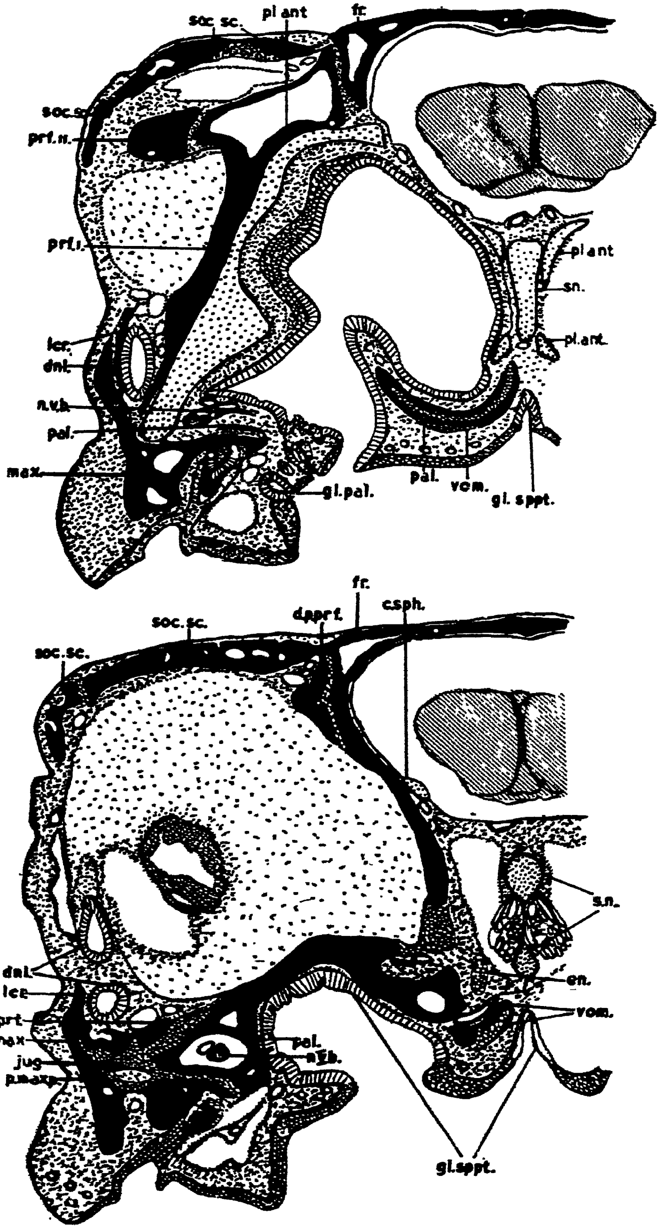

Fig. 7.—Transverse section through region immediately in front of eye. c.sph., cartilago sphenethmoidalis; d.p.prf., dorsal process of prefrontal; d.nl., ductus nasolacrimalis; e.n., eye nerve; gl.pal., glandulae palatinae; gl. sppt., glandulae sphenopterygoideae; v.p.prf., ventral process of prefrontal.

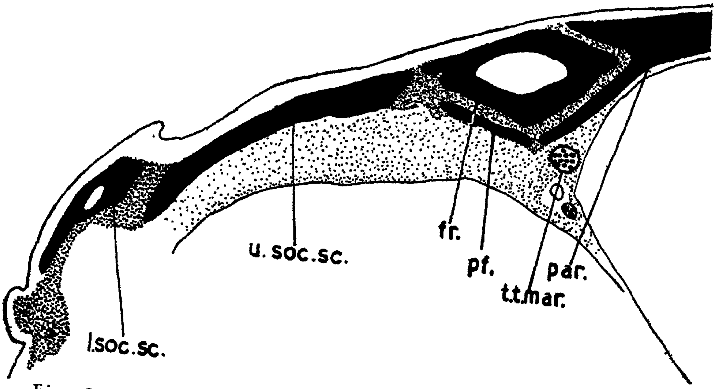

Fig. 8.—Transverse section through fronto-parietal articulation. l.soc.sc., lower supraoccular scale; pf., postfrontal; t.t.mar., taenia tecti marginalis; u.soc.sc., upper supraoccular scale.

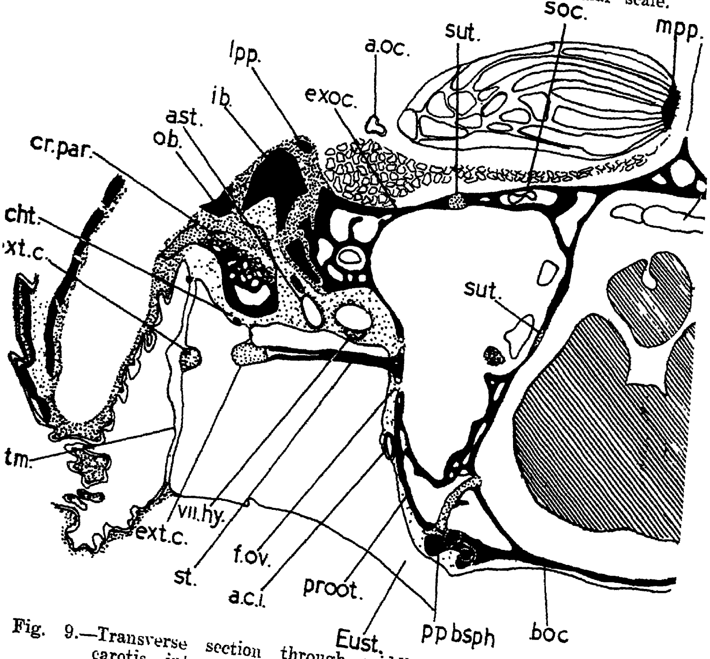

Fig. 9.—Transverse section through middle ear. a.c.i., arteria carotis interna; a.oc., arteria occipitalis; a.st., arteria stapedialis; ch.t., chorda tympani; cr.par., crista parotica; ext.c., extracolumellare; Eust., Eustachian tube; f.ov., foramen ovale; hy.VII, hyomandibular of VII; pl.c., plexus coriodeus; pro.ot., prootic; soc., supraoccipital; st., stapes sut., suture; t.m., tympanic membrane.

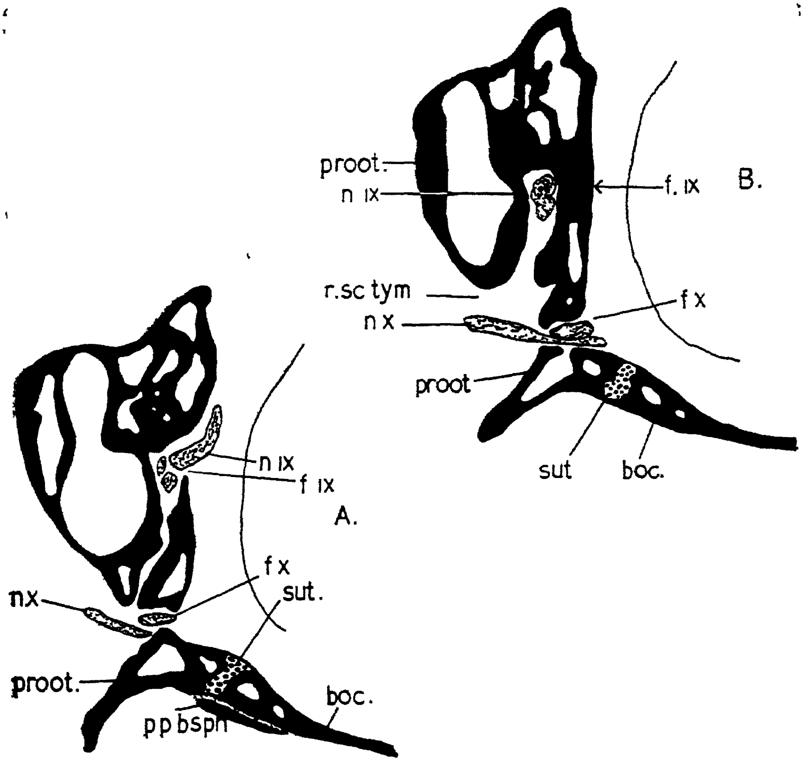

Fig 10.—Transverse section through foramina for IX and X. f.X., foramen for tenth nerve. f.IX., foramen for ninth nerve; r.sc.tym., recessus scalae tympani.

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THE ALPHA CELLS IN THE HUMAN (BANTU) ISLETS OF LANGERHANS

BY

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Read July, 1940.

In the pancreatic islets of Langerhans of all mammals so far examined two main types of cells containing granules known as alpha and beta cells are said to be present. Bloom (1931) first described these cell types in man and his main observations were confirmed by Thomas (1937) and Gomorri (1939 a). Bloom examined four human pancreases, Thomas three and Gomorri fifteen, but the pancreases were apparently obtained from necropsies. Further confirmation from studies on normal human tissues is desirable since the formation of distinct hormones is now attributed to these cell types, Gomorri (1939 b) claiming that beta cells produce insulin, whilst Bensley and Woerner (1939) prepared an extract of alpha cells said to affect fat metabolism. Before crediting the alpha cells with the production of a separate hormone, we must be reasonably certain that the alpha cells in man have their own secretory cycle as distinct from the beta cells.

This paper describes the alpha cells and all their variations in the islets of Langerhans of the pancreas in fifteen *normal* human adults (Bantu), who all died of sudden trauma, and had been under almost identical conditions during the last month or two before death. The tissues were fixed less than half an hour after death. The descriptions apply specifically only to tissues fixed in Zenker-formol and stained by the azocarmine technique (according to the modified method described by Gomorri (1939, a)).

Observations.

In the islets of man, as in animals, the main criterion for regarding a particular cell as belonging to the alpha cell type, is the presence of numerous coarse red granules. Cells filled with such characteristic granules may be called typical alpha cells.

Such typical alpha cells and cognate forms lie scattered irregularly among the other cells of the pancreatic islets, occurring singly or in groups of two, three or even five cells. Usually at least one side of a cell lies in relation to a blood vessel. Their shape is variable, round, oval, columnar or flame-shaped; cell membranes are very difficult to distinguish with certainty. In their longest diameter they measure 8 to 12 microns, but smaller and larger cells are numerous, especially in some islets. The cytoplasm has a pale blue or bluish-grey colour and contains a variable number of fairly coarse dark red or purplish-red granules. Vacuoles, appearing as small clear circular areas, are present in most cells; there are never more than eight or ten of them, scattered irregularly in the cytoplasm. Although the canals representing the Golgi apparatus are rarely seen in the alpha cells after Zenker-formol fixation, silver techniques constantly demonstrate a positive Golgi apparatus. Typical alpha cells usually have round or slightly oval nuclei lying either in the centre or in the anti-haemal pole of the cell. The longest diameters of average alpha nuclei measure 5 or 6 microns, but we have seen giant nuclei on a number of occasions although Gomorri stated there were no giant nuclei in alpha cells. There is always a very distinct nuclear membrane which usually has a regular outline. The nucleus is typically tachychromatic; the chromatin, which stains a blue or a bluish-purple colour, appears in the form of large and small granules with thin strands connecting them. Dark red nucleoli are seen in all alpha nuclei, but are extremely variable in size, number, situation and shape.

Typical alpha cells are easily recognised by their close and constant relationship to blood vessels and by containing coarse dark red granules lying in a pale greyish-blue cytoplasm.

The alpha cells of the pancreatic islets, like other glandular cells, are dynamic entities, constantly undergoing cyclical changes and reacting to physiological stimuli; these reactions are expressed in visible morphological changes, especially in their granular content and in their nuclei. On the basis of these changes the alpha cells have been divided into eight groups termed variant A1 to variant A8.

VARIANT A1 (Fig. 1): The cells in this group closely resemble the typical alpha cells, but it is characteristic of this variant that comparatively large areas of the pale greyish-blue cytoplasm contain only a few irregularly scattered coarse dark-red granules, some of which may be aggregated into small clumps. Vacuoles are sometimes seen in the cytoplasm but are relatively rare. The nucleus tends to be rather more vesicular than that of the typical alpha cell.

VARIANT A2 (Fig. 2): In this group, the cells have many more granules than in variant A1, but the increase in granular content is more or less localised to one area of the cell. No part of the cytoplasm, however, is completely devoid of granules. As in variant A1, vacuoles are not numerous. The nuclei, which are usually centrally situated, are less vesicular than in variant A1.

VARIANT A3 (Fig. 3): The cells belonging to variant A3 are the most conspicuous and often the most numerous cells of the islets in the Bantu material examined. The description of the characters of the typical alpha cell is essentially based upon this variant. The majority are oval or flame-shaped. Generally, they are the largest alpha cells and the nuclei usually lie towards the antihaemal pole of the cell. The coarse secretory granules, tightly packed together, almost completely fill the cell. There is often a small area of pale greyish-blue cytoplasm lying between the nucleus and the antihaemal pole of the cell, in which the granules are less numerous. The granules, though tightly packed, always remain discrete. Solid masses in which it is impossible to distinguish individual granules are not seen. Vacuolation of the cytoplasm, although always present to some extent, is not excessive. The nuclei of variant A3 cells are typically tachychromatic, although a few may be slightly vesicular.

VARIANT A4 (Fig. 4): The cells in this group usually have a rounded shape and they are smaller than the cells of variant A3. The cytoplasm is filled with an almost solid, dark purplish-red mass, in which—in contrast with the condition in variant A3—it is extremely difficult to distinguish individual granules. Rarely, a small area, containing only a few granules, may lie between the nucleus and the antihaemal pole of the cell. Vacuoles, irregularly scattered in the cytoplasm, are always present but are never numerous The nuclei of variant A4 cells usually differ greatly from those previously described. The majority are oval, and slightly irregular nuclear membranes are not uncommon. The chromatin material is aggregated into large masses which stain a dark bluish-purple colour. The nucleus is therefore pachy-chromatic, but pyknotic nuclei are also seen. One or two large central red nucleoli are often present.

VARIANT A5 (Fig. 5): These cells resemble those of variant A4 in many respects: They are of about the same size but usually elongated. The cytoplasm can be divided into two distinct areas, often with an abrupt juncture between the two. The antihaemal pole of the cell is completely devoid of granules and its cytoplasm has a greyish-blue colour, generally darker than the cytoplasm in variant A1 cells. This area rarely contains a few scattered granules. The other area of the cytoplasm, between the nucleus and the haemal pole of the cell, is filled with an almost solid mass of brownish red granules, darker than those seen in variant A4 cells Vacuolation of both these areas is usually a prominent feature, although the vacuoles are always small The nuclei closely resemble those of variant A4 cells, but the one or two central red nucleoli are often more prominent. A strand of nucleolar material sometimes extends from one of the nucleoli to the nuclear membrane.

VARIANT A6 (Fig. 6): It is often difficult to distinguish cells belonging to variant A6 from those of variant A2. In variant A2, although the granules are often clumped together into small masses, individual granules can always be distinguished and no part of the cytoplasm is completely devoid of granules. The antihaemal poles of variant A6 often contain no granules at all. The granules in A6 cells, instead of being a deep red as in A2, are brownish-red. The cytoplasm in variant A6 is a darker blue colour than in variant A2. The nuclei of variant A6 cells are always distinguishable from those of variant A2. They resemble the nuclei of cells belonging to variant A5, i.e. they are pachychromatic and often even pyknotic. The nuclear membranes are also slightly irregular.

VARIANT A7 (Fig. 7): Although the cells in variant A7 contain the dark red granules characteristic of alpha cells, these granules are very difficult to distinguish. The cytoplasm of these cells has a dark greyish blue colour, in which are scattered a number of dark brownish-red granules (never more than about twenty). The granules may occur anywhere in the cytoplasm but are usually commoner in the haemal pole. The cytoplasm contains many small, clear vacuoles scattered irregularly throughout the cell. The nuclei of these cells are highly characteristic They have an oval or round shape with a very irregular nuclear membrane. Individual chromatin granules cannot be distinguished, as the nucleus stains an almost uniform bluish-black colour. Two or three dark red nucleoli, lying close to the nuclear membrane, are usually present.

VARIANT A8 (Fig. 8): These cells have a pale sky blue cytoplasm, in which it is impossible to distinguish any sort of granules. The nucleus is often tachychromatic and may even be vesicular, i.e. it resembles the nuclei of variant A1 cells.

Although the above variants of alpha cells have been described as if they are entirely separate and distinct groups, it is necessary to emphasise here that cells having intermediate characteristics are numerous. In many islets there are alpha cells in which the cytoplasm contains granules similar to those of variant A3, but the nuclei resemble rather those of variant A4. Again, the nuclei of some of the agranular islet cells are intermediate in structure between those of variant A7 and A8.

DISCUSSION.

Actively functioning glandular cells present very different morphological features during the different phases of their secretory cycle, e.g. a fully granulated pancreatic acinar cell appears very different to a completely degranulated one. Such phases are much more easily recognised in exocrine than in endocrine glands, but in the latter a hitherto unrecognised stage in the secretory cycle of an accepted cell type may easily be regarded as a new type.

In order to avoid this pitfall, Gillman (1939, a) laid down certain conditions for naming a second cell type in an organ. He stated: " It is necessary to know the normal physiological fluctuations of all the cytoplasmic inclusions of the first cell type and the staining reactions in that type, to say nothing of the shape of the cell, its ontogenetic history, its responses in pathological conditions and at the same time its reactions to specific stimuli."

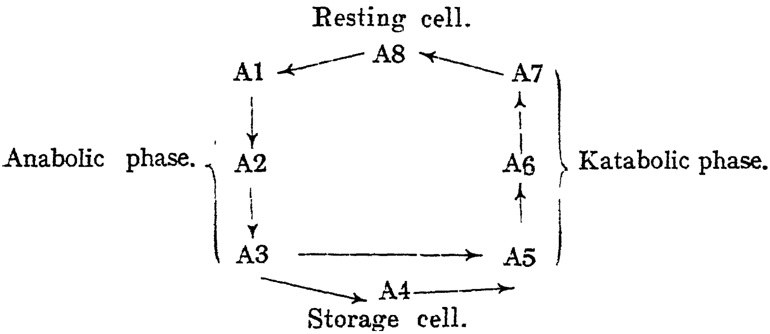
The alpha cells in the pancreatic islets are glandular cells and must therefore undergo cyclical changes associated with the secretory process. Variants A1 to A6 would be generally recognised as alpha cells because there are sufficient granules in their cytoplasm to make identification a simple matter The difficulty arises when there are insufficient typical granules present to make the identity of the cell absolutely certain. This applies particularly to those cells belonging to variants A7 and A8, which are probably identical with Bloom's D cells.

It thus follows that at one stage the alpha cell is filled with secretion (variants A3 and A4) and at another it has discharged all its secretion (variants A7 and A8). These facts further support Gillman's observations (1939, b) on human glandular tissues. He stated that the secretion of glandular cells must first be formed completely before it can be discharged and that new secretion will only form in a cell completely depleted of all its secretion.

At one stage in the elaboration of secretion there will be a certain number of granules present in the cytoplasm, whereas at a stage during the excretion of the granules there will be an equal number of granules present. This will result in a superficial similarity between the granulating and degranulating cell, which may be extremely close, as in the case of variants A2 and A6. The differentiation of such phases is of cardinal importance, since it enables us to study histologically, physiological fluctuations and variations in the islet. On the basis of this grouping of cells into anabolic and katabolic variants we can say whether the alpha cells in the islets are in the process of forming their secretion, storing it, or liberating it. By making differential cell counts it is possible to establish whether the islet is able to elaborate as much secretion as is being ejected, or whether the gland is elaborating more than is required, or finally, whether the islet is being completely exhausted.

The recognition of excretory and formative phases in the alpha cells of the islet in man is possible; but this is the first time, so far as is known, that such phases have been recognised in man. Bloom noticed that some alpha cells contained fewer granules than others, but did not infer a cyclic process in these cells.

The secretory cycle of the alpha cells in the human pancreatic islets is expressed diagrammatically as follows:—



Variant A1 represents the early phase in the elaboration of secretion. The pale sky-blue cytoplasm of variant A8 is still easily recognisable in these cells, and it is mainly on this basis and on the similar structure of the nuclei that variant A8 is considered to be a degranulated phase of the alpha cell. The vesicular nuclei of variant A1 are also an indication of early secretory activity.

In variant A2 the secretory granules continue to be elaborated until finally the fully granulated variant A3 is achieved. This variant (A3) is considered to be the final stage in the elaboration of secretion because it is the largest alpha cell and is packed with granules. When this cell has become fully granulated one of two things may happen. Either the cell immediately commences to discharge its secretion (A3—— A5) or it passes into a storage phase, represented by variant A4 (A3—— A5). When the need arises variant A4 discharges its secretion into the bloodstream (A4—— A5).

As the cell passes from variant A5 to A6, the granules are liberated until finally the cell merges into variant A7 which cell possesses only a few red granules in a dark blue cytoplasm and has an irregular pyknotic nucleus, both features characteristic of cells in a late katabolic phase. Variant A7 is the end stage of katabolism.

Variant A8 represents the recovery phase of A7 in which the cytoplasm is still blue, but the nucleus has now become more vesicular. As the cell gradually recovers both nucleus and cytoplasm stain lighter. Finally the cell is ready to start forming new granules and a new secretory cycle of the alpha cells will be initiated.

The establishment of a complete secretory cycle for the alpha cells in man provides the condition mentioned by Gillman for the differentiation of a new cell type, and for this reason we may now regard the alpha cell as a cell type, distinct from the beta cells. The establishment of a secretory cycle in the alpha cells of the pancreatic islets of man may therefore assist in furthering our knowledge of the subtle changes which occur in pathological conditions of the islets.

SUMMARY.

(1) The alpha cells in the islets of Langerhans in fifteen normal human pancreases are described and the criteria given for the recognition of typical alpha cells when fixed in Zenker-formol and stained with azocarmine.

(2) The alpha cells in the pancreatic islets are grouped into eight variants which are regarded as different stages in the granulation and degranulation of typical alpha cells, and not as different cell types. The cells in each variant are described fully.

(3) The D cells of Bloom are considered to be identical with the alpha cell variants A7 and A8.

(4) The characteristics of the alpha cells which are elaborating secretion and of those discharging it are described; the secretory cycle of the alpha cells is shown diagrammatically and the establishment of the cycle regarded as supporting the view that the alpha cells are a distinct cell type in the islets of man.

(5) Attention is drawn to the importance of the secretory cycle of the alpha cells in the study of diseases of the pancreatic islets.

I wish to express my thanks to Prof. R. A. Dart for providing facilities in his department and for his interest and advice. To Dr. Joseph Gillman I am indebted for his constant guidance throughout the course of this work and for putting at my disposal the valuable material used in this investigation. I also wish to thank Mr. T. Gillman for helping me in the preparation of this paper and for valuable suggestions; Miss R. Prinsloo for preparing the illustrations and Miss M. Tjaden for assistance with the manuscript.

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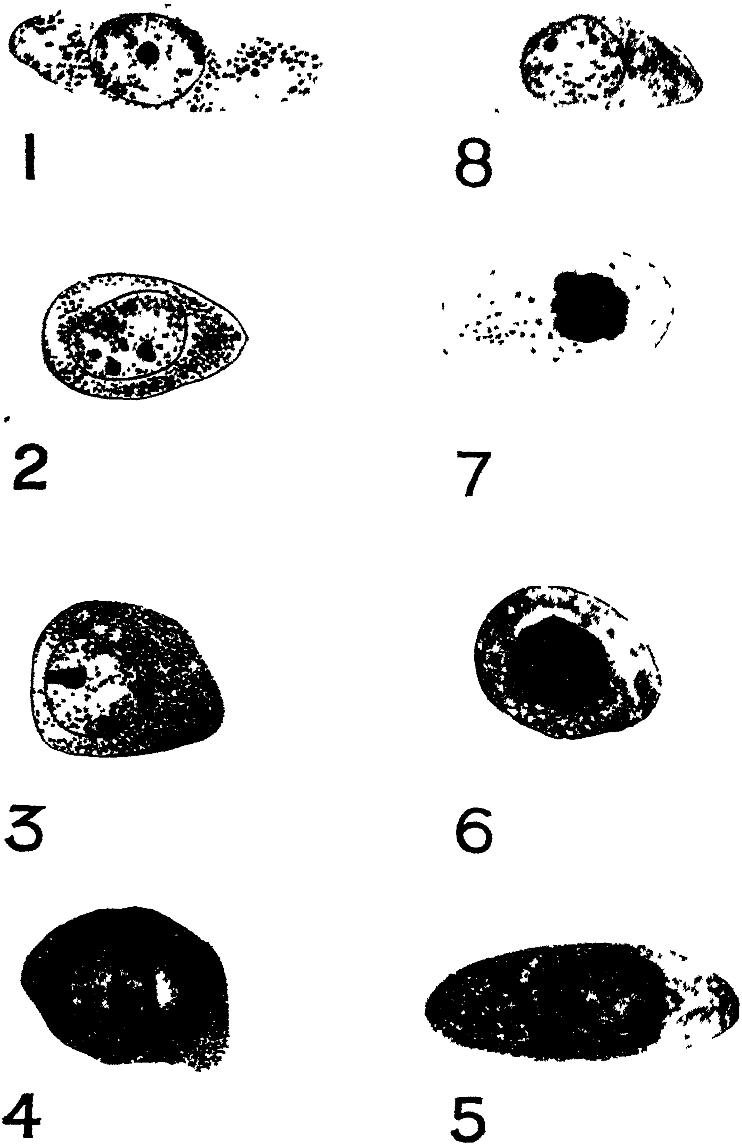
ADDENDUM. Since this paper was written, a recent article by Thomas has become accessible. T. B. Thomas, Islet tissue in the pancreas of the Elasmobranchii. *Anat. Rec.*, **76**: 1 (1940). In this article Thomas briefly described secretory cycles in the alpha, beta and D cells of the islets of elasmobranch fishes. The secretory cycle of alpha cells of the islets of man, described above, resemble in principle the observations made by Thomas. There are, however, significant differences especially in his interpretation of the D cell. These will be fully discussed in a later communication.



VARIANTS 1-8. HAEMAL POLES OF THE CELLS. X 2,000.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVII, pp.* 228-238.
February, 1941.

EARLY PHASES IN THE DEVELOPMENT OF THE MOTOR MECHANISMS OF THE SOUTH AFRICAN BABOON, *PAPIO PORCARIUS*

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With Two Text Figures.

Read 2nd July, 1940.

Recent clinical investigations of human movement patterns suggest that many of these may have been elaborated from simpler mechanisms, which served the ancestors of man for different biological purposes. The precise nature of this evolutionary process remains to be elucidated.

On studying the cinematographic films on the extra-uterine ontogenetic development of human movements prepared in Gezelle's laboratory one is immediately impressed by the close resemblance of certain postures and movement patterns, adopted in various phases of the development of the child, to the characteristic motor phenomena of the phylogenetic series of vertebrates. It is of interest to discover to what extent such ontogenetic phases may also be traced in other vertebrates.

For this purpose an investigation of the early movements of the South African baboon has been started. Several baboons have been born in our colony and we have been able to rear four of these. Moreover, Dr. Gillman has adopted the policy of accepting juvenile as well as adult baboons, so that considerable material is now available for the study of growth phenomena. Consequently it has been possible, so far, to study the major stages of the maturation of the baboon's movement patterns. Though all our observations require further confirmation some preliminary notes on the subject may be presented in this paper.

In studies like the present it is not yet possible to attain the standardisation of method elaborated by Gezelle. Our material and financial resources are very limited. Infant baboons are, moreover, not easily obtainable. They are very delicate to handle and may not afterwards be accepted back by the mother. Growth also takes place much more rapidly than in the case of the human infant. The individual component elements of the series of motor mechanisms which appear during development, follow more closely on one another than is the case in the human infant. It is therefore easier to miss certain of these when the time at one's disposal is limited.

Only pure motor mechanisms will be dealt with here. During infancy the baboon is a very tractable animal. The power of its food seeking urge is so great that it can readily be conditioned to perform a variety of tricks in order to obtain the desired food. Its repertoire of original, purposive motor activities is likewise great. These more or less complex conditioned reflexes do not fall within the scope of the present account, except in so far as they illustrate certain developmental principles.

We have been able to obtain cinematographic records of the movements of the baboon at three days and twenty-two days respectively, and possess several such records of the behaviour of juveniles and adults. For the correct interpretation of the motor behaviour of animals such records are indispensable.

The evolution of the motor behaviour patterns is rapid and it is therefore to be regretted that no observations of the infant during the first two days have been possible. The mother will not readily part with it even on the third day and the infant does not leave her spontaneously during the first few weeks. The only noteworthy motor activity of the infant on the first and second days, which has been observed so far, consists of those head movements necessary for seeking the breast and the powerful gripping action of the hands and feet, which enable the infant to cling to the mother's fur, no matter what she may be doing. It can also use its limbs for progression, dragging itself along by using both hands and feet, particularly the former.

When the infant is forcibly removed from the mother at three days and examined, the habitual posture may be determined. While the infant cannot yet raise itself on all four extremities, it can raise the front part of its body off the ground; but it much prefers to lie flat on its belly. The arms and legs tend to be fully abducted and the hands and feet are splayed out. (Fig. 1, A). It can raise its head with some difficulty and turn it from side to side. When it lies on its back or side it is unable to lift its head. At seven days the head is easily held up in this prostrate posture. The hands and feet are now more often flexed, but the legs and arms are abducted and spread out when the baboon is lying down. (Fig. 1, B). When on all fours, a posture which is already possible at this stage, the head cannot be raised or moved freely (Fig. 2, A), and the baboon views what is ahead of it by peering under its eyebrows. At twenty-two days this difficulty is still present, while the baboon is walking (Fig. 2, E-I), but, when it is stationary or when it sits up, it can freely turn its head from side to side. In later development the head becomes progressively mobilised and eventually a posture of extension can be maintained under all circumstances despite the great increase of the facial dimensions.

The righting reflex is strongly developed in the baboon in the first week of life. The infant refuses to lie on its back; it attains the prone position by rolling over. At the same time the hand and foot which are uppermost clutch at objects for support. (Fig. 1, E). As it lies on its side the uppermost limbs become extended while the lowermost ones tend to be flexed. (Fig. 2, C). Similar postures appear in the developing human child and it is important to note that they may be emphasised in certain cerebral diseases. The position of the limbs also depends to some extent on the position of the head, but the precise nature of the postural tonic neck reflexes has not yet been established satisfactorily. At twenty-two days the baboon infant is already able to maintain its balance on all fours. (Fig. 2, B). When overbalanced it still refuses to lie on its back. At this time, however, it does not *roll* back to the prone position, but it rapidly manoeuvres with all four extremities so that it recovers the four-footed stance. (Fig. 1, F). As the baboon develops, its righting activity increases correspondingly, until it eventually attains considerable agility. If tamed, its objection to lying on its back decreases and, in this position, it will often play for long periods while confident that it will not be harmed.

The activity of the tail is greatest in the early life of the baboon. In the adult, the tail, though capable of free movement, is characteristically maintained in a rigidly arched posture. On lifting the three day old baboon, powerful, lashing movements of the tail may be seen, reminiscent of an angry or excited cat's behaviour. The vigour of these lashing movements is considerable and the impulses may be transmitted to the trunk, which then seems to be jerked about. Whether these movements are purposive, either as an expression of emotion or for the maintenance of balance, has not yet been established. At twenty-two days these lashing movements of the tail are no longer much in evidence, and the arched posture is already assumed. (Fig. 2, B). In evolution, an analogous transition takes place from the fish, (in which the greatest motor activity is centralised in the tail musculature), to the vertebrates higher in the evolutionary scale, which use their limbs for the purpose of progression. In the baboon the tail is never used as a prehensile organ despite its original proportionately large size. On lifting the young baboon by the tail no such coiling takes place, as is seen in the capuchin monkey. Violent objection is registered against this kind of treatment.

The considerable power possessed by the young baboon to grip objects firmly for support, is a characteristic common to most young primates. This power is present from birth and the baboon is obliged to rely on it for its own protection. The mother appears to be fully conscious of this power for she will run, jump or fight without seeming in the least concerned about the safety of the infant clinging to her fur. The infant usually hangs on in an upright position, but may be just as secure in the inverted posture. The baboon can grip firmly not only with its hands, but also with its feet. The three day old baboon may thus be suspended by one foot without showing any alarm or discomfort. (Fig. 1, C). Its leg may become fully extended. When it is obliged to hang by one hand it immediately attempts to obtain a further grip, either with the other hand or with a foot. It will not hang with the upper extremity in extension. On the contrary, as soon as it is suspended in this manner, the arm immediately goes into flexion. (Fig. 1, D). Knowing that its grip is insecure, the infant shows considerable distress lest it should fall. This fear vanishes as soon as an adequate grip has been obtained or the infant is satisfactorily supported. At twenty-two days the baboon infant is no longer confident of its power to remain suspended by one or even two limbs. In the case of the human newly born infant the ability to hang from a bar or from fur is even more transitory.

Gripping is a flexor function. As it is essential that the infant baboon should be capable of supporting itself by clinging to its mother's fur continuously during the early days of its life, and especially while asleep, a tonic contraction of the extremities must be maintained. Emphasis is therefore given to flexor tonus and movements of flexion in general. (Such a state of flexion is also seen in the case of the human infant, although here there is no obvious purpose in the postural tonus.) The baboon mother certainly tends to support her infant when her hands are not otherwise engaged, but the infant never entirely relies on this support. While greatest prominence is thus given to flexor tonus in the young baboon, movements of extension are also readily executed. In the three days old baboon the hands and feet are splayed out on the surface on which the infant rests. In the seven days old baboon the fingers may be rigidly extended when it expresses anger or fear. Such extension is also a feature of the postures of the limbs during the execution of the righting reflex, (Fig. 1, E), and the operation of the Babinski sign. (Fig. 2, C and D).

A typical Babinski sign can be elicited in the three days old baboon. It appears readily on stroking the outer surface of the foot and consists of extension of the whole foot and fanning out of the toes. Dorsiflexion of the big toe does not occur and it is replaced by a movement of abduction. Flexion of the contralateral hand has also been observed. (Fig. 2, C and D). When the foot is already extended, no response follows cutaneous stimulation of the outer surface of the foot. No extensor plantar response can be elicited as long as the sole of the foot rests on the ground. Instead, the heel is slightly lifted from the surface of the ground. If the palm of the hand be stroked an extensor movement may also sometimes be elicited. In both cases the movement is restricted to the hand or foot segments of the limbs respectively. No support reaction has so far been observed. The Babinski sign is present only for a short period and at twenty-two days is only very doubtfully present.

The power to move over a horizontal, smooth surface is present already at the third day. The baboon infant thus differs considerably from the human child in this respect, for the latter, despite greater motor activity, remains anchored to one place for several months. The baboon of three days cannot yet raise itself on all fours, but it can raise the front part of its body and sit on its haunches. In this position it progresses backwards by pushing with both the lower extremities simultaneously. It uses the upper extremities to maintain its balance during this operation and only draws them up on completion of the move, i.e. when it has already simultaneously flexed the lower extremities again. The hands and the feet are placed flat on the surface on which the baboon is performing this movement. The fact that the hindlimbs are employed simultaneously for propelling the baboon backwards is remarkable, for in later modes of progression each limb is advanced separately. This method of locomotion is comparable to that of the frog. The fact that the baboon infant proceeds backwards is actually only due to the posture in which the limb actions operate.

Crawling with semiflexed extremities has not yet been observed. The baboon attains the plantigrade mode of progression rapidly. Thus the infant of seven days is already capable of walking on all four extremities, though very clumsily. (Fig. 2, A). The hands and feet are placed flat on the ground with the digits splayed out. At twenty-two days walking on all fours is almost fully mastered. The extremities are not yet fully extended; the forelimbs in particular are therefore relatively too long to move forwards and backwards in a single plane and are swung forwards in a semi-circular fashion by a movement of circumduction. (Fig. 2, F). The hands and feet appear to be flapped on to the surface and considerable movement occurs at the wrist and ankle joints respectively, viz. flexion as the limb is raised and extension when it is lowered. Extension at the wrist and ankle joints precedes extension of the whole limb (Fig. 2 E-I). This movement resembles the kinetic phase of the positive support reaction. The kinetic phase of the negative support reaction is likewise simulated by the sequence of flexor movements. Each limb is used separately After advancing a step, the limb is firmly applied to the surface of the ground until all the others have also moved a step forward. The gait is also somewhat ataxic at first. The animal gazes at the ground while walking and separates the limbs widely, so that a broad base is obtained. (Fig. 2, A). This manner of walking is very reminiscent of that of the tabetic individual. The human child also passes through a phase in which it employs a wide-based, stamping, ataxic gait.

In later phases the baboon gradually employs its fingers rather than its whole hand in walking on all fours and the pounding character of the movements disappears. The fingers are approximated to one another and eventually only the fingertips are used in ordinary walking, the main weight of the body being carried by the hindlimbs. The thumb is not employed, nor are the knuckles, as in the large anthropoid apes. The feet are so disproportionately long in infancy that they may tread on the hands during rapid walking, thus causing the baboon to stumble. This is due to the fact also that the lower extremities follow the upper extremities in linear progression. Later the baboon learns to walk with the hindlimbs in a plane slightly lateral to that of the forelimbs. This is also necessary in the adult when galloping, for the range of movement of the hindlimbs is greater than the length of the body. Chimpanzees may use a similar mode of progression. The oblique crawling sometimes observed in children resembles this gait somewhat.

The six months old baboon has mastered the technique of four-footed locomotion completely. After it has attained perfection in this mode of progression it soon learns to walk on only three legs. It can thus pick up an object with one hand and walk or run on the other three limbs. The extremity, when thus used, is held in flexion. Hindlimbs can also be used for holding objects when walking, but they are then also used for walking on at the same time, the foot being inverted and the weight transmitted to its outer edge.

Long before this stage has been reached the hands are already liberated for independent manipulations, while the baboon is sitting up. The next phase is introduced when it finds it possible to employ only the hindlimbs for walking. During the performance of this feat, which is not often attempted, the upper limbs at first show a tendency to assume a posture of general flexion. Later they are liberated for independent action. The hands may thus be placed on the head, as in a feat performed by one of our adult baboons, or, which is even more remarkable, the arms may be allowed to hang flaccidly at the sides, as in the human being during erect walking. This only occurs provided that the balance is secure. Similar observations have not yet been made for any other animals except certain other primates and this represents one of the highest attainments of the phylogenetic motor development. Such liberation of the arms during erect walking is repeated during the development of the human child. When the latter first commences to walk erect, its arms assume an elevated flexed position. This posture is only slowly suppressed and replaced by the lateral-flaccid position. This same elevated and flexed position is assumed by the forelimbs in all other mammals when standing erect. In the condition of hemiplegia the freedom of the affected arm is limited in a similar manner.

To summarise briefly then, the following clearly defined phases have been recognised thus far. Shortly after birth a great degree of general spasticity is observed. There is certainly nothing resembling the luxury of limb movements, which is so characteristic of the newly born human infant. This spasticity may be associated with the tonic contraction of the flexor muscles of the hands and feet, which is necessary to enable the baboon to cling to its mother's fur. The tail, however, does not share in this general restriction of movement. It is, on the contrary, excessively active. During this initial phase there is a powerful righting reflex. It should be observed, however, that such righting is at first attained by a general trunk movement and only later do the limbs play the chief role. At this stage the head also shows a great measure of fixation. The general pattern of motor activity therefore closely resembles that of a fish.

The first limb movements for locomotion are simultaneous, thrusting movements of the lower extremities. The effect of these efforts is that the baboon progresses backwards. But this is due merely to the fact that the baboon is sitting up while extending its legs. The phase is indeed comparable to the amphibian mode of progression.

A true pronograde mode of progression is not clearly recognisable. But the infant matures very rapidly and it has not yet been possible to study any of the infants continuously, especially during the first few days. It is therefore possible that this phase may be present but has not been observed.

At the next stage of development a four-footed walk is possible. But, in this first true walking, emphasis is given only to the movements of the proximal portions of the limbs. The hands and feet act as broad, flat, terminal expansions of the limbs. The walking is clumsy and not finely co-ordinated and has a pounding character. With further development extension of the hand occurs and the centre of greatest activity during walking shifts to the hindlimbs. At the same time great independent activity of the upper extremities becomes possible.

Such, broadly then, are the early phases of the evolution of the motor activity of the baboon. It is not yet possible to state the precise duration of this process of maturation or of its individual component elements; neither has it been determined yet when natural development ceases and the infant's activity becomes moulded by environmental influences. But it is obvious that these stages are shorter and more telescoped into one another than is the case in the development of the human infant.

The localisation of the centres of greatest motor activity during the development of the baboon varies in such a manner, that at each step complex movement patterns are produced, which resemble the successive motor patterns seen in phylogenetic evolution. In the case of the lower vertebrate stages the movement complexes are determined by definite states of organisation of the central nervous system, and they represent, as it were, a peripheral expression of the functions of these central organisations of the brain. But when the baboon or the human infant is born, the central nervous system is practically fully developed structurally. If the central nervous system were to function completely at this stage, as in the adult, the motor responses which would be expected would be those of a mature individual. It is thus clear that, to bring about these primitive movement patterns, various parts of the brain must begin to function in stages, which succeed one another in a characteristic order. Each of these parts of the nervous system must represent a complete unit of structural organisation. The presumption is that such units must be arranged in levels of increasing complexity, for during maturation the movement patterns become progressively more involved.

In its embryological development the primate's central nervous system rapidly passes through phases of structural organisation corresponding to the successive anatomical stages in the evolution of the nervous system during phylogeny. We do not know what motor activity the foetus shows at these stages. But it does seem likely that in extra-uterine development the functions of these structural levels are released seriatim, thus producing the remarkably close relationship between ontogenetic and phylogenetic motor patterns.

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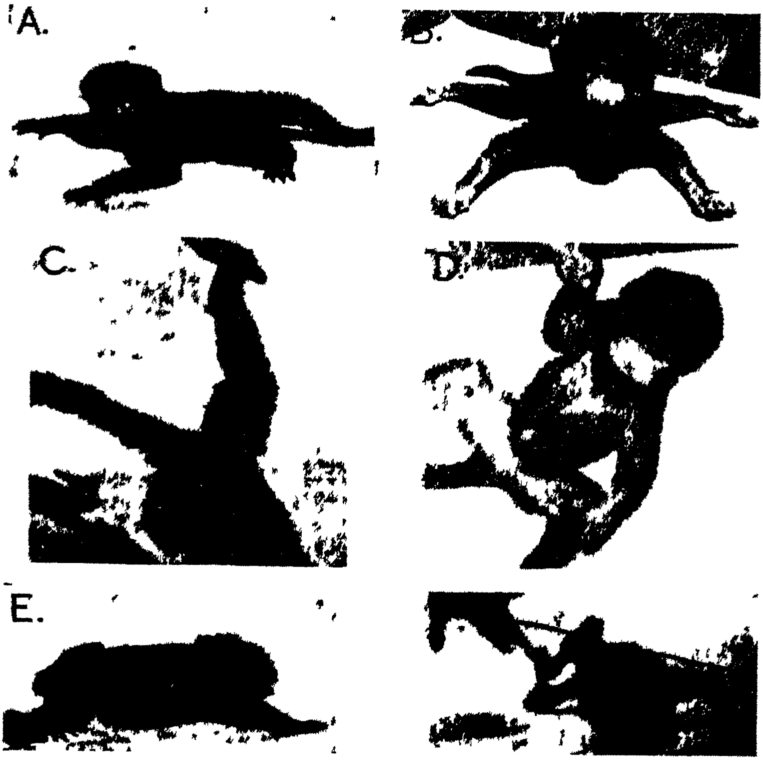

FIGURE 1.

A. Recumbent posture of the baboon infant at three days.
B. Recumbent posture of the baboon infant at seven days.
C. Three day old baboon suspended by the right hindlimb.
D. Three day old baboon suspended by the right forelimb.
E. Three day old baboon attempting to regain the prone position after its equilibrium has been disturbed.
F. Stage in the righting reflex of the twenty-two day old baboon.

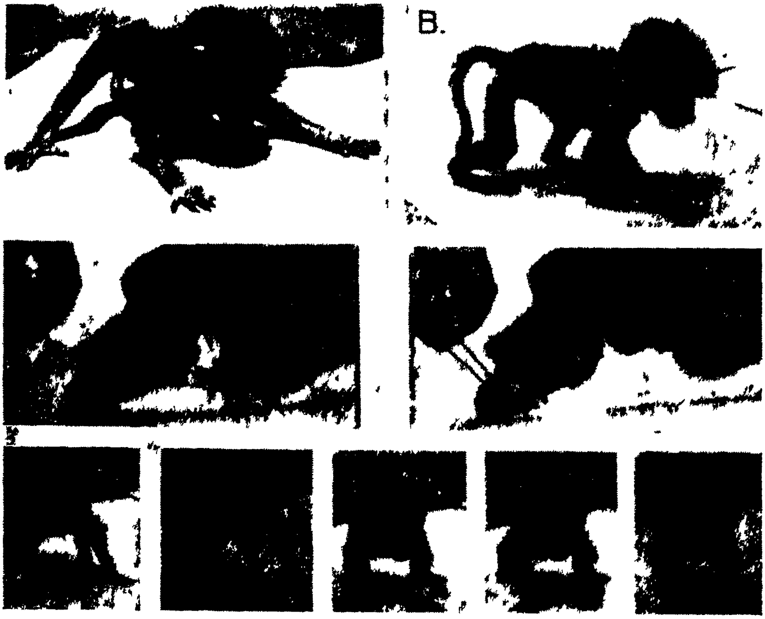

FIGURE 2.

A. Seven day old baboon walking an all four extremities.

B. Lateral view of the twenty two day old baboon. The left hind-limb has just been advanced one step.

C. Baboon of three days in the left lateral posture. Preparation being made for eliciting the Babinski sign.

D. The Babinski sign in the three day old baboon.

E. to I. Frontal view of the twenty-two day old baboon during walking.

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METHODS OF STUDY OF LIVING CELLS AS APPLIED TO THE HUMAN TESTIS

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The testis is particularly suited to the study of living cells, since each germ cell is an independent unit and its relation to adjacent cells appears to be of little significance in teased preparations.

From the available literature it appears that only one other worker has examined living human testes with supravital methods. Gatenby (1931) described the testis of a man aged 43, studied in neutral red Ringer but did not find any spermatids.

For this investigation a number of human testes were obtained very shortly after death and studied by means of paraffin and frozen sections and also by the supravital method. In this paper I wish to record the technique adopted and the structures demonstrated in the living cell.

Material. Testes were obtained from nine individuals between the ages of twenty and forty. Of these eight were Bantu and one an Indian. Some of the testes were removed within twenty minutes of death and immediately cut up, shreds being placed in suitable media, and other testes were left in the body for varying periods after death. Fragments of tissue were examined immediately, being kept under observation for an hour or more and after an interval of one to two hours were again studied, observations being then continued for a period of up to nine hours.

Criteria of Death.

Lewis and Lewis (1924) describe the stages of necrobiosis which are seen in tissue culture. When cells die gelation occurs in the protoplasm producing a granular appearance In addition changes are brought about which are indicated by the fact that supravitally stained structures lose their stain, while other bodies take it up. Finally a diffuse staining occurs in both nucleus and cytoplasm, which is particularly obvious when compared with the living cell in which the nucleus does not stain. A further criterion of cellular death which applies specifically to the mammalian testis depends on the relative elasticity of the seminiferous tubules. The living tubules are remarkably elastic and difficult to break up by teasing, but when elasticity is impaired, and teasing becomes progressively easier, many of the cells separated are either dead or dying. Unless the worker on living material keeps the criteria of necrobiosis constantly before him, the supravital technique will be even more misleading than that which involves a violent chemical treatment such as is used for fixation.

THE EFFECT OF THE TIME OF REMOVAL FROM THE BODY ON THE TESTIS.

The supravital method has been difficult to apply to human tissues, as material is rarely obtainable in a condition fresh enough for cytological study. It is therefore important to determine the effect on the tissue of the length of time afer death which elapses before the tissue is removed. It has been found that tissue removed within half an hour after death and placed in pericardial fluid as a medium lived for sixteen hours, that removed one hour after death died twelve hours afterwards, whilst testes obtained two hours after death were all dead when examined two hours later. Human remains obtained at a mortuary for supravital studies on the testes, should therefore be removed from the body within the first hour after death.

MEDIA FOR EXAMINATION.

Very little information is available as to the best media for human tissues. The following media were tried:—

1. Normal saline.
2. Ringer-Locke Solution.
2. Tyrode Solution.
4. Tyrode containing a supravital dye in concentration of 1:100,000.
5. Pericardial fluid obtained from the same body as the testis.
6. Tyrode and Pericardial fluid as 5:1.

Normal saline and Ringer-Locke solution were unsatisfactory, and Tyrode solution appears to be the best of the artificial media tried, but as De Haan (1937) had shown the value of peritoneal exudate in tissue culture, while Gailland and Variossieu (1938) had obtained spermatids in tissue culture of rat testis in plasma, it was felt that the best medium for examination would be some body fluid. The pericardial fluid from the same body as the testis proved to be the most convenient, 5 to 10 c.c. being readily obtainable at the autopsy.

According to the criteria mentioned, testis placed in pericardial fluid was still alive twelve hours later, whilst tissue placed in Tyrode and pericardial fluid showed diminished elasticity and several dead cells, and the fragments kept in pure Tyrode had almost completely succumbed. Later observations showed that under suitable conditions pericardial fluid was capable of keeping the tissue alive for sixteen hours. Dilutions of supravital dyes in Tyrode proved unsuitable and the tubules were all dead within three hours, being deeply stained and easily fragmented. Apparently in the presence of large quantities of dye, adsorption is sufficient to poison the testicular tubules.

INFLUENCE OF TEMPERATURE.

It is well known that the testis *in vivo* normally functions below body temperature and that elevated temperatures inhibit spermatogenesis. Fragments of testis kept at skin temperature for two hours died very rapidly. When tissue was obtained on hot afternoons, and kept in pericardial fluid at a temperature between 25° and 30°C, it was dead within twelve hours, whilst tissue removed at night and kept at a temperature of approximately 15°-20° remained alive for sixteen hours. It therefore appears that low temperatures are favourable for maintaining the life of the germ cells outside the body.

EXAMINATION OF UNSTAINED MATERIAL IN THE BRIGHT FIELD.

The following features of the cytology of the germ cells were observed.

1. NUCLEAR STRUCTURE. In the spermatogonium the chromatin has a faintly ragged or granular appearance; in the primary spermatocyte the changes in the chromatin associated with maturation are clearly visible. The spermatid however has a perfectly homogeneous nucleus, which emphasises the presence of certain refractile vacuoles within it. In the Sertoli cell the chromatin is faintly granular, as in the

spermatogonium, while the nuclear membrane of the living cell only very rarely shows those wrinklings and folds so characteristic of the fixed and stained Sertoli cells.

Lewis and Lewis (1924) state that "the living nucleus (in tissue culture) is optically structureless and homogeneous with both bright—and dark—field illumination." As the human germ cells examined were unquestionably alive, it would follow that their nuclei differ markedly from those recorded for cells in tissue culture.

2. Cytoplasmic Constituents. As a rule the Golgi apparatus is not visible, although in spermatids where its site is known a difference in refractive index is shown by the cytoplasm in that region. Similarly, mitochondria while visible are not sufficiently defined in the unstained cell for accurate observation. Centrioles could be seen with certainty in the spermatid and sperm only where their relation to the axial filament prevented their confusion with other cell granules. The structure of the spermatid is very clearly demonstrated, and acrosome, post-nuclear body, caudal sheath or manchette, neck region, middle piece and axial filament are all visible in appropriate stages. This study is facilitated by the lack of motility of the sperms in the testis. In the Sertoli cells the larger fat globules contain smaller vacuolations of different refractive properties. This has been described in fixed material by Gatenby and Beams (1935). They observed that "many contain a vacuole which does not stain" (with osmic acid). Owing to the peculiar fact that the crystals of Charcot-Böttcher are very scanty in the Bantu most observations on these have been made on the single testis removed from an Indian, where these crystals were plentiful.

3. Cell Size. For an accurate estimation of cell size the examination of living cells is desirable. It is well known that fixation and dehydration can produce a shrinkage of 30-50% (Baker, 1933). Furthermore, in the living cell the true diameter is measured, not the diameter of a section. Measurements of dead cells can only be relative; measurements of living cells are absolute. Even in the living cells however, factors exist which tend to alter their size. Osmotic differences in the media may produce a swelling or a shrinkage. Fortunately there are always one or two scattered red cells on the slide to act as indicators of the osmotic pressure. The effect of isolation is insignificant in the testis cells.

4. **Brownian Movement.** It is well known that granules in a cell may exhibit Brownian movement. In the cells of the testis granular inclusions exist and the presence and extent of Brownian movement in these is an index of cytoplasmic viscosity. So far it has not been possible to apply Einstein's formula for Brownian movement to these cells.

In the transition from spermatid to ripe spermatozoon the cytoplasm is stripped off. In this process a decrease in viscosity is to be expected. This is clearly demonstrated by the increase in amplitude of the Brownian movement to certain refractile granules as the cell ages. It is significant to note here that Lewis and Lewis (1924) mention that " the granules in rounded-up degenerating cells exhibit more Brownian movement than in normal cells." In this work it has even been possible to compare the extent of Brownian movement in different regions of the cytoplasm in one and the same cell.

Use of the Dark Field Microscope.

This method has been of great value in the study of Brownian movement. Owing to the amount of fat present it was unsuitable for continuous use and so cells were located and studied with the bright field before the dark field was used. The change to dark field was simple. The source of light was changed to a " Spherolux " ruby lamp, and the Abbe condenser was replaced with the cardioid type. With the eyepiece removed the light and condenser were manipulated so that the back lens of the oil-immersion objective had a bright halo of light. The objective diaphragm was then closed. This gave satisfactory illumination. The dark field is a most valuable aid in the study of spermatids. In the very earliest spermatid the dark field only shows the margin of the acrosomal vacuole; later, as this cell differentiates, the cortex of the acrosomal granule is clearly outlined, and in still older cells the whole acrosomal cap shows up as a brilliant band of light. Since the sperms do not possess such a well developed acrosome, the dark field merely outlines the anterior head cap. Furthermore the dark field demonstrates the head vacuoles, the tail filament with its naked end, the post-nuclear body and the mitochondrial sheath of the middle piece. In some cases it reveals vacuoles where their presence would not be suspected.

Referring to the dark ground and the polariscope Gatenby (1919) states that " neither of these contrivances at present provide the researcher with extensive lines of evidence." It is one of the purposes of the present work to draw attention to the value of the former contrivance.

THE POLARISING MICROSCOPE.

This has been used in the past chiefly as a control to histochemical techniques to demonstrate cholesterol. Buchthal and Knappers (1939) in their review of doubly refractive material in the cell, state that Valentin (1861) obtained anisotropy in the human sperm head whereas Schmidt (1928) did not find any. This appears to be the only observation of human male germ cells with the polariscope.

When the writer examined teased living testis with the polariscope no anisotropy was found. Gatenby (1931) suggests that the Charcot-Böttcher crystal is a lipoid storage product, but if this is so, it is evidently not an anisotropic lipoid.

Monne (1939) found the Golgi apparatus in *Helix pomatia* to be doubly refractive; this may be true for the snail, but it has not been found to exist in human germ cells.

THE SUPRAVITAL STAINING OF THE TESTIS.

Three stains were used, neutral red, Janus green and Nile blue sulphate (Grübler). As the approved brands of Janus green (Cowdry 1918) were not available the Grübler product was used and found to give good results. All the dyes were tested biologically. Neutral red and Janus green gave satisfactory results on human, jumping shrew (*Elephantulus myurus*), and amphibian blood. All three have been applied to Paramoecium and in the case of neutral red the toxicity has been very carefully worked out in this Department. The sample of Nile blue sulphate stains fat in frozen sections, as described by Lorrain Smith and Mair. The three dyes were then applied to the testis of guinea pig and rat and found to be satisfactory. Inasmuch as my sample of neutral red demonstrates the rose pink granules of Hirschler in the acrosome of Cavia, it is not inferior to the sample used by Gatenby (1929).

These dyes were all made up from 1% stock solutions in distilled water to the final dilutions in Tyrode.

NEUTRAL RED: This was used in concentrations of 1:10,000, 1:20,000 and 1:100,000. The first dilution was toxic after a few hours. Since neutral red is known to induce the appearance of a " segregation apparatus " the results of this staining cannot be analysed without further investigation.

Unlike the guinea pig sperm whose acrosome stains brightly in neutral red (Gatenby 1929), the acrosome of the human sperm does not take up the dye. This is true for all stages of spermatids except perhaps for the very earliest stage where the acrosomal granule may be faintly tinged. In my preparations the crystal of Charcot-Böttcher does not stain in neutral red. In the dark field the aggregations of neutral red bodies seen in these cells may be seen in many cases to be related to a large vacuole which is invisible in the bright field.

JANUS GREEN: This was applied in dilutions of 1:100,000 which appeared to be non-toxic. Using this dilution mitochondria take one to two hours to appear and they last for many hours with apparently little tendency to oxidise to the leuco-compound. In comparison with lymphocytes and human pancreatic cells the germ cells appear to have a relatively slower oxidation-reduction rate. Studies on the guinea pig showed that Janus green will stain the acrosome. In one human sperm this was seen. For the most part however, Janus green behaves as a specific stain for mitochondria.

The sample used provided sharp pictures of great brilliance and this is of great value in appraising the results of fixed preparation.

Rau, Brambell and Gatenby (1925) describe supravital staining of the Golgi apparatus with Janus green in Helix spermatocytes. This was not observed in any of the human cells examined.

NILE BLUE SULPHATE: In using Nile blue sulphate supravitally, its toxicity, its value as a fat stain and its other staining properties have to be considered.

With regard to the toxicity Muliyil (1936) used 0 5% solution on Lepidopteran testes and Boyle (1937) used a 1:10,000 strength on Molluscan nerve cells.

The present investigation has shown a dilution of 1:100,000 to be toxic to human testis but to permit of a few hours of study. It should be borne in mind that the use of Nile blue or other supravital dyes introduces a foreign substance which may induce structural changes and so lead to erroneous conclusions.

Muliyil says that Nile blue is "a very valuable vital dye for the determination of fats and substances closely related to fats." However, neither the fat globules of Sertoli cells—fat to osmic acid and Sudan IV—nor the Charcot-Bottcher crystals, assumed by Gatenby to be lipoid, stain with Nile blue sulphate in the living cell. This makes one very sceptical of the value of this dye as a vital fat stain and this agrees with the work of Lewis and Lewis (1915). These investigators have shown that fat globules do not stain in the living cell but do stain in fixed cells in tissue culture. In addition they show that vacuoles which stain with Nile blue in the living cell do not stain in the fixed. Although Nile blue fails to stain the fat globules of Sertoli cells or the Charcot-Böttcher crystal in the living cell, it stains granules in the cytoplasm of the spermatid and tinges the mitochondria. Its greatest value, however, lies in the remarkable property it possesses of staining the acrosome. In the very early stages even before the dark field can demonstrate its presence, Nile blue will stain the acrosome in the acrosomal vesicle. Later, however, the acrosome decreases in size and then Nile blue will tinge the anterior part of the sperm and stain deeply the posterior region of the head.

SUMMARY.

1. Living testes from nine men have been examined by supravital methods, and for the first time living human spermatids have been studied.
2. An additional criterion of death is found in the elasticity of the seminiferous tubules. When this is impaired the cells they contain are dying or dead.
3. Leaving the testis in the body for more than an hour after death, deleteriously affects the cells of the testis.
4. The cells of the excised testis live longer at a temperature lower than that of the body.
5. Human pericardial fluid is considered to be the best medium for preserving the germ cells obtained at autopsy.
6. Brownian movement demonstrates that the developing spermatid undergoes a progressive decrease in viscosity, and may be used to demonstrate variations in viscosity in one and the same cell.
7. The dark field demonstrates the acrosome in early stages of the development of the spermatid.
8. There is no anisotropic material in the seminiferous tubules.

9. The dark field technique superimposed on neutral red staining afforded information concerning the segregation of this dye in the cell.
10. Janus green (Grübler) consistently demonstrated the mitochondria in all stages of spermatogenesis.
11. Nile blue sulphate is a selective stain for the developing acrosome. Its value as a vital stain for fat is questioned.

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EXTREME POLYOVULATION AND THE FACTORS DETERMINING THE SURVIVAL OF A SINGLE EMBRYO IN EACH UTERINE HORN IN ELEPHANTULUS

BY

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Read July, 1940.

ABSTRACT.

During ovulation Elephantulus can discharge an average of 60 eggs from each ovary. This is the largest number of eggs liberated at ovulation by any mammal.

Artificial stimulation of the ovary in rodents by means of pituitary extracts have been shown to increase the number of eggs normally discharged from the ovary; but even then no instance is recorded where under these circumstances the number of eggs has been as large as in Elephantulus.

It is suggested that in Elephantulus either the pituitary produces potent gonadotropic hormones or else the ovary is unusually sensitive to normal physiological stimuli.

It has also been shown that the number of developing embryos in Elephantulus is absolutely constant. One embryo develops in each horn.

The elimination of the excess of fertilised eggs in Elephantulus is determined almost exclusively by the fact that there is only a very restricted region in each uterine horn which will allow the successful implantation of only one embryo.

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TOE SUCKING IN THE BABOON

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Read July, 1940.

Abstract.

Toe sucking has been described in two baboons, one breast and the other bottle fed. Four factors are suggested as leading to the development of this habit in bottle fed infant baboons, namely, the tendency to bite or suck, the presence of smooth objects in contact with the sensitive mouth or lips, hunger, and the liberation of the hands and feet normally used by breast fed infants in clutching the mother. In older baby baboons, loud and sudden noises, frustration, boredom, anger and hunger may provoke thumb sucking.

In breast fed infants all the stimuli that provoke thumb or toe sucking in isolated baby baboons tend to excite nipple sucking.

Thumb or toe sucking in the baboon and the human infant are compared, and evidence presented to show that this practice can be excited in both by very similar stimuli.

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THE GOLGI APPARATUS IN THE ANTERIOR LOBE OF THE NORMAL HUMAN (BANTU) PITUITARY GLAND

BY

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Read July, 1940.

ABSTRACT.

The Golgi Apparatus is described in the normal adult anterior pituitary gland cells. Changes in the form and position of the Golgi Apparatus occurring during the secretory cycle of the cell types and their variants are described. This apparatus is intimately concerned with the formation of the secretory granules, especially in the cells of Type III (Beta cells). It differentiates only after the appearance of specifically staining secretory granules, and de-differentiates after these granules have left the cell. The Golgi Apparatus adopts a form specific for Type I (Chromophobes), Type II (Alpha cells), and Type III (Beta cells) only in fully granulated or degranulated cells. Therefore, the Golgi Apparatus can be used as an indicator of cell type only in the fully differentiated cells; it is, however, in conjunction with other cell structures, a valuable indicator of secretory activity in the human anterior pituitary cells.

Observations on nuclear changes recorded by Severinghaus (1935) in the cells of the human anterior pituitary, are partly confirmed. It is considered that the Golgi Apparatus and nucleus de-differentiate completely in the degranulated cells, and that therefore, it is impossible on these criteria alone to distinguish specific Alpha or specific Beta Chromophobe cells. It is concluded that Alpha and Beta cells probably arise from non-specific Chromophobes and develop on constantly diverging lines.

Coarse, irregularly sized acidophilic granules are described in cells of Type III (Beta cells). These granules have been proved to be lipo-protein globules and not Alpha cell secretory granules. Transition forms between mature Alpha and mature Beta cells do not occur in the human pituitary.

The problem of the Golgi Apparatus as an indicator of secretory polarity is considered. In the human embryo the Golgi Apparatus is polarised towards the lumen of Rathke's pouch. During the complex development of the pituitary gland, the polarity of the cells is altered. In the adult pituitary, cells are occasionally found surrounding the lumen of an alveolus, which represents a portion of the cavity of Rathke's pouch. In such cases, the Golgi Apparatus retains its primitive polarity, and is situated between the nucleus and the luminal pole of the cell. However no regular arrangement of the Golgi Apparatus relative to blood sinusoids or cord centres, described by other authors, was observed in the Bantu anterior pituitary.

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EFFECTS OF THE IMPLANTATION OF THE MALE HUMAN ANTERIOR PITUITARY GLAND ON ENDOCRINE GLANDS OF THE FEMALE IMMATURE ALBINO RAT.

BY

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This note is presented with a view to outlining the scope of a new series of investigations which have recently been undertaken. These are primarily intended to find a reliable technique for the assay of the hormones of the human pituitary gland, and to study in detail the effect which the gland and its cellular components exert on the entire endocrine system in the albino rat. Hitherto most of the work performed has been confined, for various reasons, to the study of effects produced on the guinea-pig by the anterior pituitary glands of other animals.

There is very little indeed in the literature on the effects of implantation of the human anterior pituitary into animals. Schulze-Rhonof and Niedenthal (1928) and Zondek and Ascheim (1936) were probably the first to perform the experiment. Kunkel and Loeb (1935) stated its similarity in effect to that of the rat and rabbit when implanted into the guinea-pig. They also condemned the use of the rat for these experiments, suggesting that the stratum granulosa of the graaffian follicle was resistant to human anterior pituitary. Loeb and Saxton (1937) described the effects of implants into guinea-pigs of the anterior pituitaries of pregnant and lactating women.

In this experiment the gland was obtained 45 minutes after death, from a normal healthy male aged 30 years who died of violent trauma. It was placed immediately into Ringer-Locke solution, and then cut up into a number of small pieces. The posterior lobe was removed for acetone extraction. Then the total of one quarter of the anterior lobe was taken and implanted into the subcutaneous tissue of the back of the rat daily in four equally divided doses

The animal was killed on the fifth day and all endocrine glands removed. In addition the implant was carefully removed from the subcutaneous tissue. The entire genital tract was fixed in Bouins fluid, and the implant was fixed in Zenkeer-Formol and stained with Mallory's triple stain.

On opening the animal the changes perceivable in the genital tract were amazing. The ovaries were enlarged to at least 10 times their normal size, and enlarged follicles protruded all over the surface. The uterus was enlarged and congested. The ovary, compared with that of the control animal of the same weight and age, had increased by 400% by weight, and the uterus by 350%. On section it is clear that three effects had been exerted by the implant—

(1) A great increase in the number and size of the follicles.

(2) A Maturation effect on the granulosa, together with some Luteinisation of the theca interna.

(3) A stimulation of the interstitial gland.

The implant, stained with Mallory's, showed mainly an Alpha cell distribution, together with some chromophobes and a few Beta cells. There was much central necrosis.

Figs. 1 and 2 shew the ovaries of the control and experimental rat, magnified 20 times. Further reports will contain a detailed study of the changes in the ovaries, together with a correlation between the effects observed therein, and the histology of the implant, and studies of the other endocrine glands in these animals.

I am indebted to Professor R. A. Dart, in whose Department this investigation is being conducted, for the valuable facilities provided by him; and to Dr. Joseph Gillman, at whose instigation this study was commenced, for his advice and criticism. This paper is the first in a series published with the assistance of a grant from the National Research Council of South Africa.

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Fig.1.

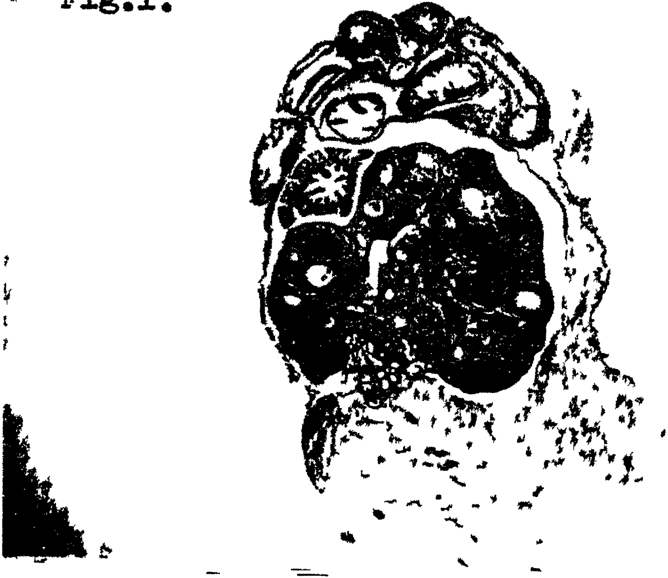
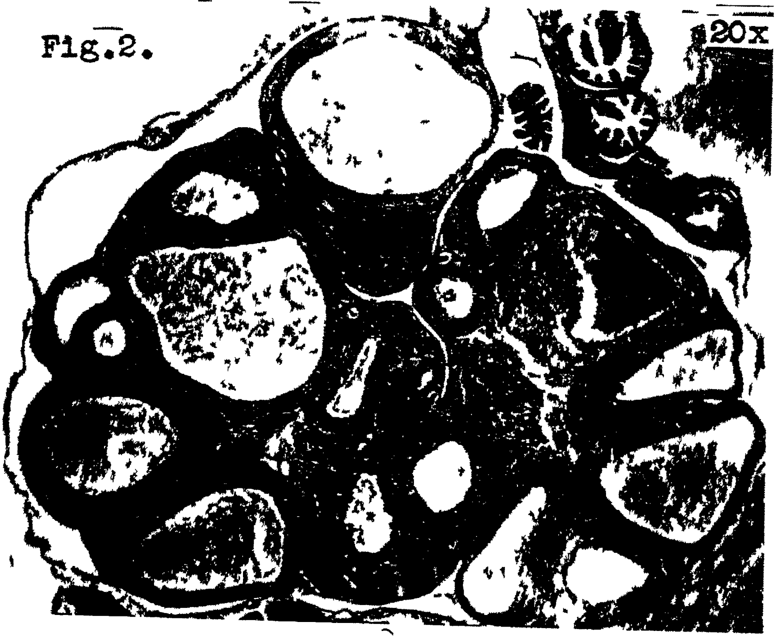


Fig.2.



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THE ASSOCIATION BETWEEN SEXUAL MATURITY. WINTER PAUSE, PERSISTENCY AND ANNUAL EGG PRODUCTION

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Sexual maturity is defined as the number of days that elapse between the date that a pullet is hatched and the date that she lays her first egg. Pullets hatched early in the breeding season mature rapidly and they commence laying at an early age. As a rule the early maturing birds are the best layers.

LITERATURE.

Rice 1915 was one of the first investigators to show an important relationship between early maturity and the rate and persistency of egg production.

Ball and Alder 1917 found that the latest maturing pullets were always poor layers.

Kennard 1921 and Kempster 1922, 25, 26 and 27, found a close relationship between early sexual maturity and high egg production. Hays and Bennett 1923 obtained an important negative correlation coefficient (r=—·438) between age at first egg and annual egg production.

Harris and Lewis 1923 explained that birds laying at an early age are in general persistent layers. Although correlation coefficients were indicated in most cases, the relationship between different years was apparently affected by other factors.

Hays 1924 and 1926 demonstrated that sexual maturity is inherited and this trait can be inbred in the stock by selecting early maturing females as breeders. Inheritance of early maturity, that is birds commencing to lay in less than 215 days of age depends upon two pairs of genes, one pair of which is sexlinked. The dominant gene of either of the two pairs of genes is capable of inducing earliness of maturity. The genes are designated E and e dominant and recessive for one pair, E' and e' dominant and recessive for the other pair. The pair E' and e' is transmitted to both sexes by males but the pair E and e is transmitted by dams to their sons, i.e. sexlinked.

Hays and Sanborn 1927 indicated that the high annual producer must be early maturing not because early maturity itself is of importance, but because early maturity has some association with high intensity and intimate association with persistency.

Warren 1934 found that the cross of a late maturing male to early maturing females produced progeny of the constitution e E' e which had a mean maturity age of 244·8 days. The early maturing females E E' E' matured in 222·2 days and the pure late maturing females e e' e' matured in 269 days. Warren explained that the sexlinked factor in combination with the autosomal factor either in homozygous or heterozygous condition produces early maturing individuals.

Time of Laying and Time of Hatching.

Ball and Alder 1917 showed that the date of hatching when kept within a two months period within the months of March, April and May did not appear to affect the total production in three years.

Hervey and Decker 1925 stated that it is not the time of hatching, but the time of maturity which determines the prospective value of the individual bird for laying purposes. Knox 1930 again found that the date of first egg has a significant association with maturity and winter egg production.

Matepial.

The results reported in this paper were secured at Grootfontein College of Agriculture 1932 to 1934.

All the chicks were not hatched at the same time. The hatching period at weekly intervals ranged from June to October. The pullets bred from dams with egg records in excess of 200 were selected and the individual egg records were secured for the first laying year.

Methods.

For the analysis of data the following measures were determined: winter clutch size, winter long pause, winter rate and persistency.

The mean winter clutch size was obtained by dividing the total number of eggs for the winter period by the number of clutches involved.

TABLE 2: CORRELATION ANALYSIS.

Factors Correlated.	Simple Correlation.	Constant factors and partial correlation coefficients.						
		Persistency.	Winter long Pause.	Winter rate.	Winter rate and Persistency.	Winter rate and Winter long pause.	Persistency and Winter long pause.	Persistency Winter rate and Winter long pause.
Sexual Maturity and Winter Prod ..	— ·368±·0416	—	—	—	—	—	—	—
Sexual Maturity and Winter clutch size	—·2871±·0442	—	—	—	—	—	—	—
Sexual Maturity and Winter rate	—·1256±·0474	—·0951±·0478	—·3066±·0436	—	—	—	—	—
Sexual Maturity and Winter long pause	—·1262±·0474	—·1448±·0471	—	—·3069±·0436	—·3004±·0438	—	—	—
Sexual Maturity and Persistency	—·1484±·0471	—	—·1644±·0469	—·1239±·0474	—	—·1052±·0476	—	—
Sexual Maturity and annual prod... ..	—·3329±·0428	—·3045±·0437	—·3894±·0409	—·3214±·0432	—·3043±·0437	—·2774±·0445	—·3629±·0418	—·2567± ·045
Winter rate and annual prod.	·5774±·0321	·5561±·0333	·5493±·0336	—	—	—	—	—
Persistency and annual prod.	·5535±·0334	—	·5488±·0337	·5356±·0343	—	·5324±·0365	—	—
Winter long pause and annual prod. ..	—·2907±·0456	—·279 ±·0444	—	·2052±·0461	·1941±·0464	—	—	—
Winter rate and persistency	·2291±·0456	—	·3022±·0438	—	—	—	—	—
Winter rate and Winter long pause	—·7085±·0239	—·7065±·0241	—	—	—	—	—	—
Winter long pause and persistency	—·1084±·0476	—	—	—·0784±·0479	—	—	—	—

Winter long pauses were ascertained by counting all pause days of four or more days in duration.

Winter rate was determined by dividing the total number of eggs from the first pullet egg to the 31st August by the number of days involved. Gericke 1933 presented an article in which he determined winter rate in a similar manner as described above. Hays and Sanborn 1927 determined net winter rate by subtracting the number of pauses from the figure obtained when dividing the total number of eggs from the first pullet egg to the end of the winter period by the number of days involved. Knox, Jull and Quinn 1935 included the pauses, a method which they consider less arbitrary than the one used by Hays and Sanborn.

Annual persistency was ascertained by counting the number of days from first pullet egg until a pause of fifteen or more days.

Correlation coefficients were determined between different measures. By means of partial correlation the influence of certain measures were eliminated.

RESULTS.

The egg production and correlation analysis for different measures are presented in tables 1 and 2.

TABLE 1. Analysis of First Year Egg Records of 197 White Leghorn Hens.

	Mean.	Standard Deviation.	Coefficient of variability.
Winter Prod. ..	67 ± ·542	11·25± ·3994	16·8 ± ·6156
Spring Prod. ..	82·15± ·5251	10·9 ± ·387	13·26± ·478
Summer-Autumn Prod.	67·04± ·8099	16·81± ·5968	25·07± ·8942
Annual Prod. ..	216·19±1·4309	29·7 ±1·0543	14·43± ·5253
Winter Clutch size..	2·41± ·0419	·8705± ·0309	36·12±1·4374
Sexual maturity (days).	169·05± ·3613	7·5 ± ·2662	4·44± ·1578
Winter long pause ..	21·57± ·6412	13·31± ·4725	61·7 ±2·9061
Winter rate ..	49·2 ± ·5357	11·12± ·3947	22·6 ± ·84
Annual Persistency	297·4 ±2·2384	46·46±1·6493	15·62± ·5683

Discussion.

Hays and Sanborn 1924 and 1926 demonstrated that sexual maturity is inherited. It is certain that variation in sexual maturity may also be influenced by nutrition and management.

Prentice Baskett and Robertson made some interesting observations of nutrition in relation to sexual maturity of White Wyandotte pullets. They emphasize the fact that the quickly matured birds are not as generally assumed, undersized and under-developed but that the best fed groups mature the most rapidly, they are the heaviest, best developed birds and the best producers. This explanation may not apply under all conditions as Funk 1933 indicated that birds which become sexually mature during the early autumn months are in many cases smaller and younger than those which begin later.

In this study it was found that pullets hatched in June and July matured sexually sometime in November and December. They continued laying until the last week in February. Then suddenly a cessation occurred in production and a large percentage moulted. Most of the pullets only dropped the neck and tail feathers (partial moult). At the beginning of the winter months (1st May) many of these pullets were still out of production. As revealed in the table below pullets hatched in June and July were poor winter layers.

Table 3. Average Annual Production of White Leghorn Hens Hatched During Different Months.

Time of Hatch.	Days to Sexual maturity.	Winter Egg Record	Annual Egg Record.
June	159	33	211
July..	163	41	218
August	168	54	221
September	171	69	226
October	173	72	207

The relationship secured between different measures is given below:

A. A significant negative correlation is indicated between sexual maturity and winter egg production (r=—·368).

B. The simple correlation coefficient is insignificant between sexual maturity and winter rate. The relationship is significant when winter pause is held constant.

C. A significant relationship is shown between winter pause and sexual maturity when winter rate and persistency are held constant.

D. The correlation coefficients are insignificant between sexual maturity and the periods spring and summer-autumn egg production.

No relationship is indicated between sexual maturity and persistency. Hays and Sanborn 1926 obtained a significant correlation between sexual maturity and persistency (r=—6146). Knox, Jull and Quinn 1935 obtained a significant negative coefficient (—·34) between sexual maturity and the last 50 days of the production year. These workers also found an insignificant negative correlation (r=—·015) between sexual maturity and the last two months of production. The production in the last 50 days and in the last two months was considered by Knox and co-workers as two different measures of persistency. The evidence which they presented does not show a linkage between sexual maturity and persistency.

Knox and co-workers 1935 found that the number of eggs laid in the last 50 days was significantly correlated with environmental factors. They also showed that the simple correlation between the number of eggs the last 50 days and Hays and Sanborn's measure of persistency is not significantly different and the two measures may be considered the same.

In the study of Knox and co-workers the number of eggs laid in the last two months is the only measure of persistency that lacks a significant correlation with sexual maturity and it has the lowest correlation with the date to hatch. Hence the number of eggs laid during the last two months of the autumn period is evidently the best measure of persistency.

As shown in tables A, B and C the results secured in the present study compare favourably with the results obtained by Knox and co-workers.

TABLE A. Correlation Coefficients secured between different measures of persistency by Knox and Co-workers and Hays and Sanborn.

	Hays and Sanborn.	Knox, Jull and Quinn.	
	Class interval of 15 days.	Last 50 days.	Last 2 months.
Simple correlation between persistency and —			
Annual production	+ ·708	+ ·667	+ ·652
Winter rate	+ ·184	+ ·150	+ ·149
Sexual maturity	— ·615	— ·340	— ·015
Date of Hatch	— ·221	— ·212	+ ·078

TABLE B. Correlation coefficients secured between two measures of persistency in the present study.

	Hays and Sanborn's method.	Last two months of autumn period.
Simple correlation between persistency and —		
Annual production	+ ·5535	+ ·6916
Winter rate	+ ·2291	+ ·0719
Sexual maturity	— ·1484	— ·0967

TABLE C. Variation in Persistency.

Measures of Persistency.	No. of Birds.	Mean.	Standard Deviation.	Coefficient of Variation.
Hays method ..	339	305 ± 1·72	48·4 ± 1·26	15·86 ± ·42
Do. ..	204	281 ± 2·66	56·4 ± 1·86	20·07 ± ·69
Do. ..	197	297·4 ± 2·24	46·46 ± 1·65	15·62 ± ·57
Last two months	197	31·5 ± ·43	11·55 ± ·30	36·6 ± 1·07

Sexual maturity is correlated to a lesser degree with production in the last two months of the autumn period than persistency with a class interval of 15 days. Sexual maturity is also correlated insignificantly with summer-autumn egg production (=—·1012±·05). If the assumption is correct that no linkage exists between sexual maturity and persistency then the last two months of the autumn period may be considered as the best measure of persistency.

A significant negative correlation is shown between sexual maturity and annual production (r=—·33±·04). After the elimination of winter rate, winter pause and persistency a slightly lower coefficient was secured (r=—·26±·04). The simple correlations between sexual maturity and total egg production obtained by Hays and Sanborn, and Knox and Co-workers are in agreement but the partial coefficients are not. Hays and Sanborn obtained an insignificant partial correlation (r=·0238± 0177). Knox and Co-workers obtained a significant negative partial correlation (r=—·479). The latter workers state that this seeming lack of agreement may be due to the highly significant simple correlation (5956) which Hays and Sanborn obtained between sexual maturity and their particular measure of persistency.

A rather intimate correlation is shown between winter rate and annual egg production (r= 5774). Hays and Sanborn 1927 obtained a simple correlation of ·4769±·0104 between these measures. Knox and Co-workers obtained a high simple correlation between the same traits. The latter workers indicated that winter rate is much to be preferred to the more generally used measures of rate as winter production and winter pause.

The correlation between winter pause and annual production is significant (r=—·2097). Hays and Sanborn and Knox and co-workers found important negative correlations between these measures. The latter workers found that winter pause is not only significantly correlated with environmental factors, but as a reciprocal is more or less a statistical duplication of the percentage of winter production.

A positive simple correlation is shown between winter rate and persistency (r=·2291). Hays and Sanborn 1926 obtained a simple correlation of ·1835 between these rate traits. They indicated that in general there is some tendency for the more intense layers to persist in laying later in the autumn period than the less intense layers.

No relationship is indicated between winter pause and persistency (r=—·1084). The elimination of winter rate reduced the coefficient to ·0784. Hays and Sanborn obtained an insignificant simple correlation between these traits (r=·1017±·0182). After eliminating age at first egg winter clutch size and days broody, Hays and Sanborn 1927 obtained a partial correlation of —0393±·0183. These results establish the fact that winter pause and persistency are independent traits.

SUMMARY.

a. Early hatched chicks (1st June to 15th July) frequently moult in March and April. The moult may continue until the first half of the winter months and egg production is affected adversely.

b. Winter egg production and sexual maturity are correlated significantly.

c. The correlation coefficients are insignificant between sexual maturity and the periods spring and summer-autumn production.

d. Sexual maturity and persistency of laying are separate traits.

e. Sexual maturity is significantly correlated with annual egg production.

f. Winter pause and persistency are independent measures.

g. The date of hatch, sexual maturity, winter rate of laying and persistency in the last two months of the autumn period are important measures to consider in the breeding of high egg producers.

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BIRDS OF THE PRIMEVAL FOREST AT "BELMONT" (MELSETTER).

BY

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During the early years of this century, particularly from 1905 to 1908, the late Mr. C. F. M. Swynnerton was actively engaged in studying the avifauna of Mt. Selinda forest, as well as the birds of other parts of the Melsetter District.

His discoveries were outstanding and included the addition to the African List of a number of birds which were then entirely unknown to Science. Not only were new *species* found to be inhabiting the forest at Selinda, but new *genera*

Since those days various scientific expeditions have visited the forest, and as a general rule made large collections of the indigenous birds from those parts, many of which have found their way to American museums and not a few to the museums of Africa. It would appear that the bird population of the forest has not suffered to any serious extent from these activities, as the expeditions have not been too numerous, and a period of time has elapsed between visits which has allowed the birds to breed again, and so repopulate the area.

Unfortunately one species of Robin (*Pogonocichla swynnertoni*), Shelley or Swynnerton's Bush-Robin—previously known as *Erythracus swynnertoni*—seems to have entirely vanished from the Selinda forest; this fact was borne out by Mr. Swynnerton himself during the very last visit he made to his farm Gungunyana, the homestead of which is built within the confines of the forest. He told me how common this species used to be and expressed much regret at its complete disappearance; he said he saw none at all and that only a few years ago these robins were to be seen from the verandah of his house.

No scientific records published after 1910 mention this species as having been collected at Mt. Selinda, so one can but suppose that the variety has become exceedingly scarce, or even extinct on account of its confiding nature and inability to extricate itself from Native bird traps, which are said to be numerous within the forest. This particular robin has not been re-discovered in any other part of Rhodesia, except near Umtali, where Mr. P. A. Sheppard noted it some years ago.

As the bird distribution of the Selinda forest is so unique, it occurred to me that it might be duplicated in other parts of the Eastern Border, where even still unknown species might be found; consequently in the month of May of 1939 as well as in 1940, a special survey of a forest patch, which is situated on Belmont Farm some five miles East of Melsetter, was made.

Through the courtesy of Capt. Saunders and Mr. Bredenkamp—who are joint owners of Belmont forest—observations started on May 14th, 1939, when the first bird previously supposed to be confined to the Selinda forest was collected This species belongs to the Thrush family and it known as *Turdus olivaceus swynnertoni* Bannerman. It is an interesting bird, insomuch that the effect of environment has caused Swynnerton's Thrush or the Chirinda Olive Thrush to become many shades darker than its cousin *Turdus libonyanus libonyanus,* Smith, or the Kurrichane Thrush which we may see commonly in Salisbury.

About a dozen varieties of birds which dwell in these dense forests, never leave the confines of the forest; they feed therein, breed therein and pass the whole of their existence in the dank undergrowth which is cast into still deeper shadow by the giant *albizzias* or by the numerous *dracaenas* and lianas which abound everywhere. Herein are countless insects and a great variety of berries; food is plentiful all the year round, undoubtedly of a richer nature than that which would be obtained outside the forest during the dry months of the year: as a result of this we see the pigment of the feathers affected; the forest-loving birds become darker and more adapted to their surroundings, although, as will be pointed out later, some birds become more vivid in plumage, but these few kinds take special advantage of the patches of sunshine which penetrate the gloom here and there, and so harmonise with the brilliant pale green and lemon shades of the vegetation that they become inconspicuous.

Another interesting example of forest-loving influence is well exemplified in *Aplopelia larvata larvata* (Temm. & Knip). One at once realises how the general coloration of the Lemon Dove assimilates with the shade of the undergrowth, where this bird spends most of its time on the ground among the fallen leaves of mahoganies or some of the various species of Ficus, whose leaves have turned to russet brown. Swynnerton found this Dove common at Mt. Selinda, where it is still so, but except for its reappearance at the Belmont Forest I have heard of no other distributional records in Southern Rhodesia. A female specimen obtained on May 16th, 1939, had been feeding on green berries, this food had also been supplemented by numbers of large black ants. During many hours spent in the forest no call or utterance of any kind was heard which could have been attributed to the Lemon Dove, although one often heard the Wood Doves (*Turtur chalcospilos chalcospilos*) (Wagl.) breaking the stillness of within by their peculiarly mournful notes.

It is about sixty miles from the forest at Mt. Selinda to that at Belmont, Melsetter. It would be reasonable to suppose that some of the Forest birds do reside in suitable localities between those two places, especially as I have discovered that certain types of the Selinda bird fauna do reside on the Inyanga Downs, where there are stretches of heavily entangled *gwashas* (overgrown ravines). But in spite of this, no reeords of the birds peculiar to Selinda have appeared there as yet. The glades of the Chimanimani Mountains are ideal for their distribution too, and it is to be hoped that a combined expedition composed of botanists, entomologists and ornithologists will be able to find their way there at a later date.

Three species of Bulbul, well known at Selinda were recorded at Belmont forest. The most plentiful of these is *Phyllastrephus flavostriatus flavostriatus*, Sharpe, the Yellow-streaker Bulbul; the next in evidence were *Arizelocichla milanjensis milanjensis*, Shelley, the Milanji Stripe-cheeked Greenbul, and lastly, of rare occurrence, in the forest, *Phyllastrephus terrestris swahelicus*, Reich, the Nyasa Scrub-Bulbul. It was tascinating to watch parties of these different kinds of Bulbuls, and to listen to their extremely varied calls and notes of alarm. Generally speaking their notes are harsh and grating when they are on the alert or feeding in company; but on many occasions these birds sing melodiously. The Yellow-streaked are great feeders on insects, and may be observed creeping like mice or hopping like frogs from bough to bough, as they comb out all the likely places where insects are secreted. It was most amusing to watch one bird in particular ascend a two-inch-thick liana, which was hanging down from a height of at least sixty feet. The upward journey was made from near ground level by a continued series of vertical bounds, each of but a few inches at a time; first the bird would ascend with its head well to the right of the living rope and in a second the next move had been made with the head to the left of the rope, so that a series of these jumps made in quick succession gave one the impression that the pendulum of a metronome was rapidly ascending heavenwards. Should a beetle, etc., be encountered on the way up it vanished in a moment, and not till the bird reached the top of the liana did it change over to another mode of progression, which was creeping, mouse-like amongst the tallest fern-like fronds of the Albizzias.

Of the Shrike family *Chlorophoneus nigrifrons manningi* (Shelley) the Rhodesian Black-fronted Bush-Shrike, was recorded in Belmont forest on May 19th, 1939, and again on April 28th, 1940. Previous to this it has only been known at Selinda. It is essentially a forest Shrike, and it is noteworthy that birds of this species are particularly partial to a very dark green leafed tree whch is prolific in the forest; the Shrikes—rarely more than a pair—search the leaves thoroughly for small beetles and insects hopping lightly and silently from twig to twig. They are hard to see amongst the foliage, and it has been found that the only way really successfully to observe forest birds is to remain motionless in the same spot for a considerable time with eyes fixed on a specied area; on a still day the slightest movement is apparent.

Muscicapidae (Flycatchers) are numerous in the forest, the commonest being *Batis capensis erythropthalma* (Swynn), the Chirinda Puffback Flycatcher. It might be as well to explain that the word Chirinda was always utilised by Swynnerton for the place we now call Mount Selinda, consequently the old nomenclature has been retained in Scientific works of to-day. By no means scarce is *Trochocercus albonotatus swynnertoni* (Neum), the beautiful Gazaland White-tailed Flycatcher. Both of these species are fond of taking up a stance in a sun-lit patch, usually on a dead branch many feet up from the ground, and it is a pretty sight to watch them fly-catching as one or another darts through a forest glade. The White-tailed variety utilise their tails to a great extent when in flight, and the conspicuous white edging to the tail when it is spread out fan-shaped is a simple form of identification to this rather sombre plumaged bird—another good example of a true type of forest fly-catcher. The slight crest on the head is raised at times and sharp shrill notes are uttered now and again, as the birds change their station and wish to keep in touch with one another.

The most interesting discovery of all at Belmont forest was the recording of *Pogonocichla stellata transvaalensis*, Roberts, the White-starred Bush-Robin. On May 18th, 1939, it was seen in an isolated forest patch on Capt. Allott's farm, and on April 28th, 1940, it was found to be in the main forest on Capt. Saunders' land. In general appearance it is not unlike Swynnerton's Robin (*P. swynnertoni*), Shelley, but lacks the white throat band, and in the distance one was led to believe at first that that very rare bird had at last been rediscovered. Stellata is a secretive bird; extremely shy and rarely stays in the same place for a fraction of a second; it spends most of its time in deep shade, very often with its back to one, and is consequently inconspicuous: when, however, it does confront one it is usually in a diminutive patch of sunlight, and in spite of its bright lemon-coloured underparts, is again very hard to see as the sunlight on the green and yellow leaves and on the bird itself, gives one the impression that it is part of the surrounding undergrowth. Again, it is only by movement on the part of the bird and by absolute tranquility on the part of the observer that it seems likely one will ever see this attractive Robin. There is little doubt that these birds—as well as numerous other species—do spot a stranger in the forest, however still he may be; but it is entirely owing to the fact that he remains still that the birds gain confidence and show themselves more or less in the open, which they would never do if even slightly alarmed. The "stars" of brilliant lustrous white feathers—like enamel—are a feature of this species, and are only visible when the bird is in the hand.

Finally, *Nectarinia kilimensis arturi*, the Mashonaland Bronzy Sunbird, so well known to Swynnerton, was found to be very widely distributed outside the confines of the forest, where numerous pairs or family parties were seen busily feeding among wild blue salvia, which grew on the lower stretches of the hills in great profusion.

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February, 1941.

CHARACTERISTICS OF THE FRESH-WATER MOLLUSC FOUND IN SOUTHERN RHODESIA AND THE UNION OF SOUTH AFRICA AND POPULARLY KNOWN AS *PHYSOPSIS AFRICANA* KRAUSS

BY

F. GORDON CAWSTON, *Durban.*

Received July, 1940.

ABSTRACT.

Without knowledge of their soft anatomy identification of molluscs is largely tentative but the shell of *Physopsis africana* Krauss is sufficiently distinctive not to be confused with allied species. Its truncate columella forms a definite tunnel so that the empty shell may be supported on a pin, but this formation causes the living specimen, if disturbed, to drop rather easily from a leaf in the water.

Different species of mollusc favour different kinds of plants so that these either favour or hinder their breeding Such food influences the shape of the teeth in their radula.

Typical examples of *Physopsis africana* Krauss are more common in the Union of South Africa than farther north, where similar species occur which may conceivably interbreed, but attempts by the author to produce hybrids from interbreeding with an imported snail have failed.

Heavy infestation of a species of mollusc with certain parasites may serve as a guide to its identity.

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A CONSIDERATION OF THE RESISTANCE OF MOLLUSCS AND MAMMALS TO THE ATTACKS OF LARVAL TREMATODES

BY

F. GORDON CAWSTON, *Durban.*

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ABSTRACT.

Parasitism of both molluscs and mammals varies and individuals of the same species vary in their power of resistance.

Only a small number of schistosomes which invade the skin ever develop to maturity in the liver-substance.

Sometimes a larva remains at the site where it penetrates the skin and thus produces a local skin rash, such as Sandworm disease which can be caused by a parasitic worm which develops to its full growth in domestic pets.

Most parasitic worms which enter the skin reach the liver before developing further, but recent experiments serve to show that they may sometimes grow into the adult stage without such migration and schistosomes are found in the nostrils of mules through infestion produced by drinking from tanks containing the necessary molluscan host.

We are at present ignorant of some of the factors involved in a successful demonstration of the life-cycle of the liver-fluke.

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THE PROBLEM OF SOUTH AFRICAN TURF IN RELATION TO INVERTEBRATE PESTS.

BY

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Read July, 1940.

Natural turf exists in Southern Africa, but it is a rarity. In most parts of this country it is a delicate artificial creation requiring constant care. In Northern Europe on the other hand, natural turf is abundant and can be maintained with a minimum of effort: climatic conditions are favourable and, furthermore, there is an abundance of earthworms which keeps the soil aerated. Pests are numerous in Europe but do little damage. They have been long established and a natural balance has been achieved. To attempt the eradication of such pests is dangerous. If their numbers are decreased below the normal level, natural control is upset; they afterwards enjoy a period of partial immunity. The most satisfactory way of dealing with well established pests is to increase the resistance of the turf by careful manuring and general treatment. In this way, and in this way alone, can a really satisfactory and permanent turf be established.

In Southern Africa the establishment of a permanent turf capable of fighting its own battles is a counsel of perfection. Such a position may be ultimately attained but it may be hundreds and perhaps thousands of years before this happy consummation. The turf is a new creation, composed of indigenous grasses in a new environment, and its pests are new pests. The majority, it is true, are South African endemics, which have existed in the veld from time immemorial, but as pests of turf they are new. Active measures are needed for their control.

New pests behave in a different manner from old ones. After a long period of years most organisms reach a position of stability, in which there numbers fluctuate but little about the mean. A new pest is unstable and its numbers tend to fluctuate widely. Such pests do serious damage.

New pests may pass through a " latent period " after which they suddenly increase in numbers so greatly that their host plants, over wide areas, are seriously damaged or even exterminated. The " latent period " probably extends over several generations. It appears to be a period of acclimatization. That such adaptation occurs and is spread over a number of generations seems well established. It might well be expected to result in a steadily increasing population, but in our experience, it often seems to make little noticeable difference to the abundance of the organism until a certain point is reached, when there is a sudden increase. It would appear that at this point the whole population overcomes the last of the resistant factors of the environment and is free to advance. If this be so it cannot well be a process of the natural selection of chance variations, but must be a mass transformation such as is recorded as occurring in the colouration of rodents, etc. We have no explanation to offer. All that can safely be said is that immigrants into a new environment rarely prosper at first, only after a number of generations do they become acclimatized: they then increase greatly. Thus, with new pests, the initial period of destruction is the most severe; it is usually followed by a series of ever decreasing waves until at length the fluctuations are damped out and the organism ceases to be a menace. If, however, climatic or other disturbances, periodically or occasionally, decrease its numbers, such decreases will be followed by increases when damage will be done. Permanent pests are those which, through climatic conditions, are frequently greatly reduced: so continuing to fluctuate widely in their numbers.

The danger to South African turf is great. New pests are present and the army of potential pests is large—probably greater than in any other part of the world with the possible exception of South America. This can be explained as follows:—

The Northern Hemisphere consists chiefly of land masses and the polar region is not isolated from these by a wide expanse of ocean. In consequence the climate varies considerably from place to place and from season to season, while any variation which takes place in the amount of solar radiation produces extensive climatic changes. During the Pleistocene the Northern Hemisphere experienced Ice Ages and Pluvial Periods, when the polar ice cap alternately advanced and receded and great changes in precipitation took place. These changes were accompanied by considerable alterations in land levels. A number of the less adaptable forms of life were thus destroyed, while new species, which possessed a hardy constitution and a capacity to flourish under a wide range of conditions, were evoked.

The flora and fauna of the sub-arctic and temperate zones of the Northern Hemisphere are characterised by such vigorous and adaptable species, which have, in some cases, extended their range to the tropics. Wherever they have penetrated they have wrought destruction, greatly diminishing the variety of competitive species. In the Pleistocene and Post-Pleistocene, their range was restricted to some degree by natural barriers, yet, in some cases their range extended through both Palaearctic and Nearctic regions. To-day the increase of cultivation, the construction of roads, and the presence of rapid transport have removed these barriers, and the range of many dominant species is rapidly extending. The destruction of the flora and fauna of the world has proceeded during the last 100 years at a rate rarely or never before experienced in its history. It is still accelerating, and the terrestrial flora and fauna of the whole world is now decreasing at a phenomenal pace.

The surface of the Southern Hemisphere consists principally of water, and the land masses of its temperate zone are isolated from the polar land mass by a wide expanse of ocean. Owing to the thermostatic effect of this large body of water it experienced no Pleistocene ice ages and the pluvial periods were less marked. South Africa itself forms part of a very ancient land mass, and during this period of the earth's history it was not subjected to the intense volcanic activity and the changes in level which were so marked a feature of the Northern Hemisphere. The climate no doubt fluctuated; but these fluctuations were small. The large stable land mass had a dry climate, and the fluctuations in humidity which took place had little effect upon the flora and fauna. It is clear that in a semi-arid region fluctuations of 50%, in either direction, in the average annual rainfall can have much less effect on the flora and fauna than an equal percentage fluctuation in a humid region.

The climate of South Africa, associated as it is with a shallow soil, is unfavourable to the growth of forests. There can be little doubt that, despite the fluctuations of the Pleistocene, somewhat arid conditions have prevailed for millions of years, and that open veld has been the predominant oecological formation In consequence, the land has a somewhat sparse covering of vegetation: each plant requires a considerable area of soil from which to draw its water. There is none of the struggle for light and aerial growing space which is so marked a feature of humid regions. The plants fight against the physical environment rather than with each other.

The veld, although it gives an impression of uniformity, is in reality a widely varied formation, differing from place to place and often containing a number of distinct habitats in an area of less than an acre. Dry open lands offer a uniform environment to large animals, but to plants and invertebrates they consist of a varied collection of distinct micro-environments which are often well isolated. Specialization has consequently been encouraged. Plants have become adapted to every nook and cranny of the environment. The flora is in consequence amongst the richest in the world. The variety of plant life has multiplied the micro-environments of the smaller fauna and, in consequence, its richness is even greater than that of the flora.

Owing to the equable climate and the absence of internecine war, the fauna of South Africa, which at the end of the Pliocene, probably differed little from that of the Palaearctic, was conserved and pursued a tranquil course, while the Tertiary fauna of the Northern Hemisphere was decimated. This was also greatly assisted by the isolation which it enjoyed. It was protected from the ingress of the dominant species of the Palaearctic by three barriers:—

(1) The tropic zone: which, if meteorologists are correct, was hotter during parts of the Pleistocene than it is to-day.

(2) The Sahara Desert: which was established before the Pleistocene and although it fluctuated somewhat in size (diminishing during the pluvial periods and expanding in the intervening dry periods) yet, throughout, maintained its integrity; forming a wide and formidable barrier to both animals and plants.

(3) The great sterile areas of Northern Central Africa: where the flora and fauna was much reduced. The exact period of this destruction cannot with certainty be fixed, nor

its cause as yet determined. It probably extended well into the Pleistocene and we believe the cause to have been volcanic activity.

The richness of the South African flora and fauna and its resemblance to the Tertiary flora and fauna of the Palaearctic is due chiefly to the following factors:—

(1) No cataclysmic variations in climate have occurred since early in the Tertiary Period.
(2) The immigration of Pleistocene species has been prevented by natural barriers.
(3) The struggle for existence has been against the environment rather than amongst the individuals.
(4) The number of micro-environments has been, and still is, large, and their degree of isolation considerable, owing to the dryness of the climate.

A large proportion of the great host of veld-dwelling invertebrates normally eat grass and others may be expected to adapt themselves easily to such a diet. Some attack the roots, some eat the leaves, while yet others nourish themselves on the seeds. There can be few parts of the world where the potential pests of turf are so numerous.

All grass-eating organisms cannot be regarded as pests by the green-keeper. Those that browse or suck the sap may often prove a blessing; they reduce the labour of mowing. The amount of grass eaten by insects is large and, although it may benefit the green-keeper, it is a heavy loss to the farmer. Twenty small caterpillars per sq. yard, uniformly distributed over a field one acre in extent, would devour as much grass per day as would a large ox. Such an infestation would not appear heavy, and it is probable that on good turf the amount of grass devoured by insects much exceeds this Where the turf is well established the insects which mow the grass in this manner, grasshoppers, caterpillars, and the like, may be regarded as beneficial, as may be the host of sucking insects which retard leaf growth; unless they produce lesions through which micro-organisms enter the plants. That this occurs on some greens we have reason to believe although as yet we have no certain proof.

The majority of turf pests are root feeders which when they become numerous either themselves destroy the turf—as does *Macrophylla sp.*—or so weaken it that at the first drought it wilts and dies. Organisms which burrow in the soil and throw up mounds, or cause irregularities on the surface, must be regarded as pests, although they may themselves do no direct damage. In some cases these forms produce irregularities which cause damage when the green is mown—as does Gryllotalpa—while in others they produce mounds and casts which make the surface of the green unsuited to play. The most important of these are ants and earthworms. The ants may usually be regarded as a real pest, although in some places the fact that they destroy numbers of Elaterid beetles, whose larva, the "wire worm," is a root feeder, may make them well worthy of conservation The earthworms cannot be regarded as a pest save under exceptional circumstances.

South African turf, composed as it is of indigenous grasses placed in a new environment, is in a precarious position. The number of pests already doing damage is considerable and the damage in some places is severe, while there is a large number of potential pests now living in the veld, which have either never yet invaded the turf or which are still in the latent period. With the high condition of culture and prosperity which is so marked in South Africa to-day, the demand for good turf is great and steadily increasing. With this increase the number of pests is likely to increase, and, unless measures are taken to combat them, disappointment and cost of maintenance will increase even faster. The pests already attacking the turf are little known, and the potential pests still less understood. If they are to be actively combated their life histories and habits must be known, and no mistake must be made as to their species. The importance of correct determination is clear when we consider the *Macrophylla spp.* The species at Mossel Bay although apparently the same as that found at Port Elizabeth has different habits and can be combated by different means. In the present state of our knowledge the determination of the species of Macrophylla is a matter of uncertainty.

It is on this account that we have started a small research station at Rhodes College to investigate the pests of African turf. We trust that all members of the association who notice organisms damaging turf will assist us by sending material accompanied by as much data as to habits, time of appearance. localities, and the nature of the attack, as they can collect.

In this connection we would like to record our thanks to Mr. T. D. Hall, Mr. D. Meredith and Mr. S. M. Murray for their co-operation and keen observations, and also to the many golf clubs and other sporting bodies who have assisted us. We wish also to thank Mr. Geo. Haines and Mr. H. Bishop for their co-operation in field experiments.

The turf pests so far brought to our notice are as follows:

Coleoptera: Scarabaeidae: *Macrophylla nigricollis* Per.?

This cockchafer, which cannot yet be certainly identified, occurs along the coastal belt of the South Eastern Cape. We have taken it from the golf courses at Port Alfred, Humewood (Port Elizabeth), and in the natural vegetation at Kasouga and at the Bushmans River. On golf courses extensive damage is done to the turf on both greens and fairways.

The larvae are root feeders and when near the surface destroy the grass roots. When present in large numbers the larvae can create havoc in green or fairway; large areas are "scalped" and sections of the turf can be picked up like a carpet, the entire root system having been destroyed. The damage shows up suddenly, particularly after a dry period, usually towards the end of November or early December.

Mr. G. J. Arrow remarks, "The two large beetles are *Melolonthines* of the genus Macrophylla. One is a male, and the other a female, but it is not certain if they belong to the same species. We have several specimens of this genus in the collection but previously we had no female specimens Peringuey's catalogue of South African Coleoptera lists five species of this genus, in four of which the female sex was unknown. The male specimen sent by you should be compared with *M. nigricollis* Per , but its identity must remain doubtful. You will see, therefore, that the species of this genus are not well known, and nothing in detail seems to be known about their habits."

With reference to the above we can definitely state that the female sent to the British Museum was of the same species as the male, as we noticed these copulating.

Mr. Arrow has pointed out that females are not often seen and we can confirm this. One or two have been taken at the surface where they were surrounded by males. Another female was taken at Humewood on 3rd March, 1939, at a depth of 3 feet in the soil where she had deposited eggs.

This species of Macrophylla comes on the wing during January, and the flying beetles have generally disappeared by the middle of March. They do not fly during the day but just before sunset numerous males take to the wing. They are readily attracted to light at night and many thousands of males have been caught in light traps at both Port Alfred and Humewood. We have never yet taken a female in a light trap, nor seen a female on the wing.

When making excavations at different times we have found all stages of the larvae, but have not yet found the pupal stage.

The control measures tried include surface applications of lead arsenate, at different times of the year; depth applications of a soil fumigant containing paradichlorbenzene and soil injections with carbon bisulphide. Other methods have also been tried, but the above chemical methods give most promise as larvicides. Light traps will catch males but the benefit of this is very doubtful. The destruction of the elusive female would be a sound method of attack, but, as yet, no satisfactory method has been evolved.

Macrophylla sp.

A beetle closely related to *M. nigricollis* has been recorded as a pest from the Mossel Bay Golf course.

The damage it causes is identical with that done by *M. nigricollis* and is if anything more severe.

The habits of this beetle are however somewhat different. The adult males come on the wing after rains about the middle of January, and fly around for at most two or three days during the daytime from about 10 a.m. to 4 p.m. when they go back into the ground. The female beetles do not fly, but crawl about for short periods, after which they immediately burrow into the ground and are followed by several males.

Soil injections of carbon bisulphide have proved successful as a larvicide. With this beetle the female does show itself for short periods and hence control measures which are aimed at the females are practicable. Many hundreds are collected and destroyed during the two or three days in January when the adults are active.

Anomala vetula Wied.

The beetles have been found in large numbers on greens at Port Alfred. Mr. Arrow remarks that there are apparently no records of this or any other species of Anomala actually assuming the proportions of a pest; but as they are all feeders on the roots of grasses, it is quite easy to suppose that one or more of them may assume that status.

Hybosorus illigeri Reiche.

This beetle has been taken in large numbers from turf at Messina in the Northern Transvaal. It is one of the commonest Scarabaeids in all Africa and one which also extends into Southern Europe, Asia Minor, Southern Arabia, etc.

Though it is so common, there seems to be no published information about its biology. Sir Guy Marshall recalls it as one of the commonest Scarabaeids on the grassy veld, appearing in large numbers after rain. Neither he nor Dr. Hugh Scott can see any reason why it should not be a pest of turf, that is to say, a root feeder. Mr. Arrow, on the other hand is very doubtful of this, and thinks it probable that the insect feeds in manure or decaying vegetable matter.

Control measures adopted against this beetle included the use of lead arsenate and a soil fumigant; both had the effect of considerably improving the green.

Heteronychus tristis Boh.

The pest has been recorded on turf from the south coast of Natal at Umbogintwini.

The damage it does is similar to that done by *M. nigricollis*, but in this case the grass is not "scalped" by the larvae. By feeding on the roots the normal growth of grass is retarded. Mr. Arrow remarks that members of this genus are well known to attack the roots of various grasses, and two of them have been recorded as pests of maize and sugar-cane in South Africa.

Arsenate of lead and soil fumigants have been tried, the latter proving more effective.

Lepidoptera: Bombyces: *Gorgopis libania.*

This pest was named by Dr. T. J. Naude. So far we have only recorded it from turf on the State Mines, Witwatersrand.

The larva makes a vertical shaft in the turf, in some cases up to twelve inches deep. On the surface a web is spun under which it attacks the grass, eating well defined runs. Later the larva closes the mouth of the shaft with a cap and pupates.

A mechanical method of control is adopted. Either before or after the caps are made, the shafts are pierced by means of long sharpened lengths of wire, thus killing the larvae or pupae. Old oil can also be poured down the burrows. In both cases, however, the control measures are only undertaken after the damage has been done, and early (December) application of lead arsenate spray may be effective, although this has not yet been tried.

Hemiptera Heteroptera: Lygaeidae: *Nysius natalensis* Evans, *Geocoris moderatus* Montandon.

These bugs have been found in great numbers on turf on the Rand at State Mines and at Frankenwald, and have always been associated.

Specimens were named by Mr. W. E. China, who points out that the species of Nysius were revised some years ago by Dr. Evans. *G. moderatus* is widely distributed round a large part of Africa in the thorn-scrub belt of the country.

We have not yet definitely established that these Lygaeidae are pests of turf: there is certainly no record of their assuming that status. On the other hand, they have been present on greens in large numbers and their appearance has been associated with poor turf. When controlled with an insecticide such as a derris root preparation, there has been an improvement of the turf.

Saltatoria: Gryllidae: *Gryllotalpa africana* P.-B.

This mole-cricket has been recorded as a pest of turf from Durban and the South Coast at Umbogintwini.

Specimens were named by Dr. B. P. Uvarov who remarks that the species occurs all over the tropics and subtropics of the Old World.

As far as turf is concerned the main damage done by mole-crickets appears on putting and bowling greens. Where the infestation is bad the smooth close-cut surface of the turf is ruined by the little mounds and burrows which the insects make in their wanderings just below the surface. Later, when the greens have to be cut, the closely set mower tears off the tops of the little mounds and protruding grass roots, with the consequent disfigurement of the turf. Numerous repetitions of this ruin the greens.

Lead arsenate has not proved successful, but injections of powerful soil fumigants have been successful.

Arachnida: Acarina: Trombidiidae: *Stigmaeus sp.*

So far we have recorded this species of mite only from the Witwatersrand. It has been found in large numbers on the greens at the State Mines Golf Course and on experimental plots at Frankenwald.

Infestations of the mite cause a strange hypertrophy in the grass shoots. The growth takes the form of proliferations in which the leaves are much reduced in size and closely overlap each other forming an elongated rosette. At the bases of these leaves all stages of the mite are found and their appearance is frequently accompanied by a brown colouration.

Dr. R. T. Lawrence remarks that in America the genus occurs on the imbricated leaves of pineapples, bamboos, etc. It belongs to the same family as the red-spider Tetranychus which is of economic importance. In Stigmaeus the punctures of the mite give access, in some cases, to certain destructive fungi.

Control measures tried include the use of derris preparations, plain and in conjunction with soft soap and an oil spray, nicotine sulphate with soap and with an oil spray, fumigation with a cyanide preparation, the use of colloidal, wettable and lime sulphur; and nicotine dust. So far the cyanide treatment is the only one which shows promise.

OTHER GROUPS. In addition to the above little known pests and potential pests of turf, there are others which are more common and about which we do not intend to say much at this juncture. These include nematodes, ants, termites, earthworms and crickets. These pests occur in turf in all parts of South Africa to a greater or less degree.

Ants can be a nuisance at times and two specimens, taken from Umbogintwini, which we sent to the British Museum were identified by Mr. H. St. J. K. Donisthorpe.

Tetramorium sericiventre Emy. subsp. *continentalis* Forel. This usually nests in the ground surrounded by a more or less circular wall of earth. It is carnivorous, cultivates root aphidae, collects seeds, and is fond of sweets, etc.

Pheidole punctulata Mayr. This nests in the ground, often under leaves, etc. It collects seeds, is partial to sugar and is frequently a pest in houses.

Ants can be controlled by the use of poison baits or the nests can be treated directly with petrol or cyanide.

Termites are a real menace and there is perhaps no insect pest about which we receive so many complaints, particularly in the Transvaal and Natal. The harvester termites can be controlled by the use of sweetened poison bait, while the fungus-growing termites are best controlled by means of an arsenic-sulphur blower or by pouring petrol or carbon bisulphide down the main runs.

Earthworms, particularly the genus Microchaeta of which there are fourteen species, and the smaller Acanthodriline worms, unfortunately may, under certain circumstances, have to be regarded as a pest of turf. In some soils their casts, when numerous and when they have dried, make accurate putting impossible and to the bowler they are even more annoying. Brushing the green with a besom in the early morning is usually sufficient to eliminate this, but where necessary the worms can be controlled by surface applications of lead arsenate.

We have noticed crickets on golf courses along the south coast of Natal. They eat the grass around the entrance to their burrows and in this way harm the turf. Poison baits are an effective control measure.

SUMMARY.

1. The factors making it probable that turf is more subject to pests than other cultivated vegetation in South Africa are theoretically discussed, and an attempt is made to show that new pests do more damage than old pests.

2. Isolation and oecological conditions in the Tertiary and Post Tertiary periods have resulted in a remarkably varied and specialized veld fauna. Turf, consisting as it does in most parts of the country of indigenous grasses in a new environment, has many enemies, most of which may be expected to behave as new pests.

3. The types of damage done by invertebrates are considered, and certain new or little known pests are recorded and briefly discussed.

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PALATAL MEASUREMENTS OF NEGRO AND OTHER CRANIA

BY

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With 2 Tables.

Read 2nd July, 1940.

Introduction.

For some years the author has been engaged on a metrical study of South African aboriginal skulls. The analysis of those measurements which concern the dental arcade and palate revealed striking differences between certain South African Negro groups. At the same time, these measurements displayed a variability which appeared remarkably great, and which threw doubt on the utility of metrical features of this part of the skull as criteria for racial diagnosis.

In the hope of elucidating these problems, the author while working in the Museum of the Royal College of Surgeons during 1938 collected palatal measurements on several additional series of skulls. These comprised two further African Negro groups, one of Batetela (Congo) and the other of Gaboon Negro skulls, and two extra-African series which exemplified extreme variations in palatal form, viz., an Australian and a Chinese group. Comparison of these observations with those previously collected in South Africa has proved highly instructive. The bearing of these results upon the variability and consequently the validity of palatal measurements will be discussed in another paper. Here it is sufficient to remark that, as a result of the wide range of these measurements in all the series examined, and consequently of the extensive overlap between one group and another, palatal measurements of an individual specimen can only exceptionally be diagnostic of race. Significant differences of palatal form, emerge only when considerable series of skulls are compared statistically. This paper deals with such differences as they have been encountered in the material under review.

Five absolute measurements and three indices have been employed in this study. The maxillo-alveolar (external palatal) and the (internal) palatal diameters and indices are well-known measurements; these were determined according to the technique of Martin (1928), the palatal breadth being measured to the *base* of the palatal spine. In addition, the bicanine diameter was measured as the maximum transverse diameter upon the alveolus external to the canine tooth, and its relation to the maxillo-alveolar (bimolar) breadth expressed as an index (bicanine index). These last observations have been suggested by the remarks of Sir Arthur Keith (1925). They had previously been employed in individual cases by several observers, but their behaviour in large series does not appear to have been studied prior to this investigation.

The crania studied comprised, in the first place, 54 Basuto and 48 Zulu specimens belonging to the collections of this Department. As the differences between these two series, both metrical and morphological, are of the slightest, they have been combined in a single South-east African Negro group. An Ovambo series, loaned by the South African Museum, Cape Town, included some 30 skulls on which these measurements were obtainable. The South African Bush race is represented by approximately 120 skulls, including specimens belonging to this Department, to the Port Elizabeth Museum, and to the McGregor Memorial Museum, Kimberley, (the bicanine diameter was not measured upon the Kimberley Museum material). At the Royal College of Surgeons 105 Australian, 55 Chinese, 64 Batetela and 32 Gaboon crania were measured. In the case of the Batetela series the internal palatal measurements were unfortunately omitted; it had been hoped that those of Bennington (1912) on this series might have been utilised, but his technique of measurement proves to be different from that used in this study. All of these series except the Chinese included individual skulls upon which all the measurements could not be taken, the number of skulls measured in each case being shown in Table I. This table shows the range, mean, standard error and standard deviation of each measurement for the several groups. The significance of the differences between the means is shown in Table 2.

DESCRIPTION OF OBSERVATIONS.

1. ABSOLUTE MEASUREMENTS: While the limits of variation in maxillo-alveolar length vary somewhat from group to group, the extent of the range is very much the same in all except the Batetela, among whom there are no markedly elongated alveolar arches. The mean values for this measurement range from the great length seen in the Australian and to a less extent in the South-east African Negro, through the intermediate type represented by the Gaboon Negro, to the relative shortness of the Ovambo, Batetela, Bush and Chinese groups. These latter groups show differences which are at the most of doubtful significance, whereas the more elongate types are separated by probably or definitely significant differences.

The differences in the range of the maxillo-alveolar breadth are less than in the length measurement, the Bush group having the widest range and the Batetela and Gaboon Negro narrowest. In the mean values there is a regular progression from the broadest to the narrowest measurement, each group differing from the next in order only by an insignificant amount. A broad distinction can however be established between the wide arcades of the Australian, South-East African Negro and Ovambo, the intermediate values for the Chinese and the Gaboon Negro, and the narrow measurements of the Batetela and Bush groups.

In the case of the (internal) palatal length, the range of variation differs very considerably from group to group, being about twice as much in the South-East African Negro and in the Australian as in the Chinese. The mean values are sharply divided into two groups, the elongate palates of the Australian, Gaboon Negro and South-East African Negro contrasting with the much shorter Chinese, Ovambo and Bush types. It must be pointed out, however, that the Ovambo mean is derived from a very small number of specimens. Palatal breadth has an appreciably wider range in the South-East African Negro than in the other groups. The mean values for this measurement are remarkably consistent, showing differences which are never more than doubtfully significant, except for the high Ovambo mean which differs significantly from all except the South-East African Negro.

Since the maxillo-alveolar and palatal breadths are measured in approximately the same plane, the difference between them affords an indication of the massiveness of the molar alveolar ridge This difference is appreciably less in the Bush than in any other group, implying that this ridge is here very slender. The contrast is most clearly displayed when the Bush group is compared with the Chinese, the palatal breadths of the two groups being practically identical, while their maxillo-alveolar breadths are significantly different. Between the groups other than the Bush the differences are comparatively small, the large Australian and South-East African Negro palates appearing to have slightly thicker alveolar ridges than the smaller types.

The range of the bicanine measurement is greatest in the Batetela group, which includes the lowest values encountered. It is also rather larger in the Australian and South-East African Negro groups than in the remainder. These groups include the highest values observed, but none of these equal the measurement found in the Broken Hill skull (53 mm.). In the mean value for this measurement the Australian group strikingly exceeds the others. The Bush and Batetela groups have the smallest mean values; these show probably significant differences from the remaining groups whose means are almost identical. Sir Arthur Keith (1925) gives this measurement for the European as "44 mm. or less", a value comparable with those of the groups studied except for the Australian.

2. INDICES: In the case of the maxillo-alveolar index, the range of variation is consistently high. It is least in the Australian and Chinese groups, covering some twenty-eight units in each. The extreme values are however very different in these two groups, the lowest value among the Chinese coinciding with the mean of the Australian series Among the African series, the South-East African Negro, Batetela and Gaboon Negro have much wider ranges (thirty-seven or thirty-eight units), almost equalling in extent the conjoint ranges of the Australian and Chinese groups. The ranges of the Ovambo and Bush series are intermediate in extent.

The mean values for this index in the Chinese, Batetela and Ovambo groups fall into the brachyuranic class of Turner, showing that these groups tend to possess broad alveolar arcades. In the other groups the mean values are mesuranic or even, in the case of the Australian, dolichuranic, the alveolar arcade being of a generally more elongated character. These two palatal forms are marked off from one another by significant differences, except for that between the brachyuranic Ovambo and the mesuranic Bush which is only doubtfully significant. This exception may be explained in part by the small number of Ovambo measurements, for the only slightly larger differences between the Bush and the Batetela is significant. At all events there is a sharp demarcation between the broad alveolar arcades of the Ovambo and Batetela, and the elongate ones of the South-East African and Gaboon Negro. That of the Australian is still more elongate, being significantly different from all the African groups except the Gaboon Negro.

For the palatal index the range of variation is also consistently large. It is greatest in the South-East African Negro group, owing to the occurrence of exceptionally low indices, whereas the Gaboon Negro has the narrowest range, due to the absence of very high values. Of the mean values, that of the Bush (and also that of the Ovambo so far as the few available figures can be relied upon) belongs to the brachystaphyline or broad division of this index. The differences between the values for these groups and for the Chinese are however only doubtfully significant, although the latter falls into the intermediate mesostaphyline category. On the other hand, there is a probably significant difference between the Chinese and the South-East African Negro, whose mean lies below the upper limit of the leptostaphyline or narrow division. The Australian and the Gaboon Negro have still lower values, i.e. narrower palates, differing significantly from the South-East African Negro.

In the bicanine index, as in the bicanine diameter, the Batetela group has the widest range, its extreme values enclosing those of all the other African groups. Of the extra-African groups, the Chinese has a relatively narrow range; this is due to the absence of low values, the upper limit coinciding with that of the Batetela. The Australian range is also restricted at its lower end, but its upper limit is extended considerably beyond those of the other groups. Compared with the African groups, therefore, the Australian includes many more values above 70 and fewer below 60. In consequence, the mean value for the Australian is considerably higher than for any other group, being significantly different from all except possibly the Gaboon Negro. The means of the remaining groups vary very little; only the difference between the extreme values, Gaboon Negro and Ovambo, is of more than doubtful significance. Sir Arthur Keith declares the value of this index in the European to be "usually 62", a figure comparable with that for the Ovambo, and tending to be slightly but perhaps not significantly less than those of the other African groups. It may be added that the value of this index in the Broken Hill skull (68), is within the range of variation of all the groups studied, and close to the Australian mean. Thus the distinctive character of the Broken Hill palate depends on its absolute and not on its relative breadth in this region.

3. SUMMARY OF GROUP CHARACTERS: Table 1 shows that the Australian palate has large mean values for all absolute measurements with the exception of palatal breadth. It is decidedly elongated, being on the average dolichuranic and markedly leptostaphyline, but is especially distinguished by the high value of the bicanine index. The Chinese palate, having small anteroposterior and moderate transverse diameters, is relatively much broader, being brachyuranic and mesostaphyline; its bicanine index is moderate.

Of the African groups, the South-East African Negro makes the nearest approach to the Australian in the means of its absolute measurements, the anteroposterior diameters being somewhat smaller, the transverse, except for the bicanine breadth, approximately the same. The palate is therefore not so elongated, being mesuranic and less markedly leptostaphyline, while the bicanine index is moderate. While the Gaboon Negro is smaller than the South-East African Negro in all diameters except palatal length, it resembles the Australian more nearly in its markedly leptostaphyline palatal index and relatively high bicanine index. On the other hand the Ovambo palate, with moderate or small diameters, except for its large palatal breadth, is conspicuously different in form, being brachyuranic and so far as can be determined brachystaphyline, its bicanine index is low. In the case of the Batetela the external diameters which alone are available, are consistently small. This group also is brachyuranic and has a low bicanine index. The Bush group likewise shows small means for all absolute measurements, except the palatal breadth which is relatively larger than the other diameters owing to the slenderness of the molar alveolar ridges. Because of this it is mesuranic but brachystaphyline, while the bicanine index is moderate

DISCUSSION.

The outstanding result of this survey is the wide range of form displayed by the dental arcade and palate of African

Negro groups. While the Gaboon Negro, and to a less marked degree the South-East African Negro, possess elongated dental arcades and narrow palates which approach the Australian type, the Ovambo and Batetela have broad dental arcades resembling those of the Chinese.

These findings afford clear evidence of the complex ancestry of the African Negro peoples. They indicate that at least two elements with sharply contrasted palatal forms have gone to the making of these groups. One of these may be presumed to have possessed an elongated palate similar to that of the Australian, which has been preserved by the Gaboon Negro, and with a greater degree of admixture by the South-East African Negro. A second element must have given rise to the small, relatively broad dental arcade of the Batetela. The similarities of this to the Chinese palate are probably fortuitous; its small dimensions suggest a Bush or Pygmy origin. Considering the measurements of the Bush series in this connection, it is essential to remember that this material includes an appreciable South-East African Negro admixture, and almost certainly other foreign elements in addition.

The short, but notably broad, dental arcade of the Ovambo might perhaps be explained as a further product of the fusion of these two elements, by a process analogous to those invoked by Dreyer, Meiring and Hoffman (1938) in the case of variations in cranial form. It is however probable that yet other ancestral forms have to be dealt with. Even setting aside the exceptionally broad dental arcade of the Broken Hill skull, it must be remembered that our knowledge of the palate of pre-Bushman types in Southern Africa is, except in the case of the Fish Hoek skull, extremely meagre.

This study has also shown that the South-East African Negro displays a particularly high range of variation in both internal palatal measurements and in the palatal index. The range of variation of the maxillo-alveolar index is also high in this group, but is equalled by those of the Batetela and the Gaboon Negro, the former of which possesses the greatest range of variation in both the bicanine diameter and the bicanine index. It is possible that such wide variations in absolute and relative measurements are due to the hybrid origin of these Negro groups. However, a high range of variation is shown in several measurements and indices by the Australian group, which might be supposed to be relatively homogeneous.

The observations made on the bicanine diameter and index in this material indicates that these measurements are worthy of more extensive investigation. While the clearest distinction established in this study is between the Australian and the other groups, the variation among these latter, though not conclusively significant, is suggestive of distinctions as yet imperfectly revealed. Further, the remarks of Sir Arthur Keith on this diameter and index in the European, offer the possibility that these may prove to be still smaller than in some of the African types.

SUMMARY.

A statistical analysis of measurements and indices of the dental arcade and palate has been made in four African Negro groups (South-East African Negro, Ovambo, Batetela and Gaboon Negro) and also in the Bush, Australian Aboriginal and Chinese. The distinctive features of each of these groups are summarised in an earlier section of this paper. There is a conspicuous difference in palatal form between the Negro groups, which is regarded as evidence of the composite origin of the African Negro peoples. In the South African and in the Gaboon Negroes the palate is long and narrow; it resembles that of the Australian native but is narrower in front. Those of the Ovambo and the Batetela are short and broad. The difference between these and the other Negro groups is probably due to an infusion of Bushman or Pygmy blood. The bicanine index appears to be of some value in racial identification.

ACKNOWLEDGMENTS.

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TABLE I. MEASUREMENTS AND INDICES

	Maxillo—Alveolar Length				Maxillo—Alveolar Breadth				Palatal Length.		
	No.	Range	Mean ± SE.	S D.	No.	Range	Mean ± SE.	S.D.	No.	Range	Mean ± SE.
S.-E. African Negro ..	96	48·0 — 67·0	57·87 ± 0·72	3·48	96	54·0 — 73·0	64·71 ± 0·72	3·48	99	41·0 — 63·0	49·03 ± 0·88
Ovambo	31	43·0 — 61·0	53·67 ± 1·42	4·02	30	58·0 — 75·0	64·70 ± 1·58	4·32	16	36·0 — 53·0	44·63 ± 2·16
Batetela	63	44·0 — 56·0	51·21 ± 0·82	3·26	64	53·0 — 68·5	60·58 ± 0·98	3·89	—	—	—
Gaboon Negro ..	31	47·0 — 64·5	55·47 ± 1·50	4·16	29	53·5 — 69·0	62·00 ± 1·40	3·77	31	42·5 — 57·0	49·81 ± 1·18
Bush	109	42·0 — 61·0	52·11 ± 0·68	3·52	106	50·0 — 70·9	59·44 ± 0·70	3·60	89	37·0 — 55·0	43·43 ± 0·72
Australian	105	48·0 — 70·0	59·24 ± 0·80	4·04	105	55·0 — 72·7	65·26 ± 0·74	3·78	104	42·6 — 63·0	51·75 ± 0·70
Chinese	55	46·2 — 61·5	52·61 ± 0·90	3·34	55	52·0 — 67·8	63·26 ± 0·86	3·16	55	39·8 — 50·2	44·98 ± 0·74

	Bicanine Breadth				Maxillo—Alveolar Index				Palatal Index		
	No.	Range	Mean ± SE	S.D.	No.	Range	Mean ± SE.	S.D.	No.	Range	Mean ± SE.
S.-E. African Negro ..	99	35·0 — 50·0	41·46 ± 0·54	2·70	96	95·3 — 132·7	112·31 ± 1·52	7·41	98	53·4 — 100·0	78·61 ± 1·96
Ovambo	27	36·0 — 46·0	40·17 ± 1·06	2·76	30	103·1 — 134·9	117·20 ± 2·82	7·77	15	64·7 — 102·8	88·60 ± 4·38
Batetela	63	30·5 — 48·5	38·06 ± 1·04	4·10	63	98·1 — 136·2	118·33 ± 1·90	7·56	—	—	—
Gaboon Negro ..	30	35·0 — 45·0	40·30 ± 0·96	2·51	28	99·1 — 136·2	111·54 ± 3·02	8·01	28	60·5 — 83·7	71·50 ± 2·30
Bush	80	33·0 — 43·0	38·61 ± 0·54	2·42	102	100·0 — 130·2	113·72 ± 1·22	6·20	89	68·8 — 102·3	86·75 ± 1·76
Australian	105	35·0 — 49·4	43·55 ± 0·56	2·88	105	97·5 — 125·0	109·38 ± 1·16	5·92	104	59·1 — 96·4	73·21 ± 1·26
Chinese	55	34·0 — 45·8	41·02 ± 0·70	2·62	55	109·0 — 137·0	120·65 ± 1·78	6·60	55	66·3 — 98·6	83·62 ± 2·08

Palatal Breadth

S D	No	Range	Mean ± SE.	S D.
4·34	101	31·0 — 51·0	38·38 ± 0·68	3·43
4·30	30	33·0 — 46·0	39·63 ± 1·04	2·57
—	—	—	—	—
3 30	30	29 0 — 43·0	36 70 ± 1·20	3·27
3·40	108	30·0 — 46 0	37 44 ± 0·60	3·14
3 60	105	32·0 — 48 0	37·69 ± 0·60	3 10
2·72	55	28·5 — 43·4	37·51 ± 0·76	2·82

Bicanine Index

S D	No	Range	Mean ± SE	S D.
9·00	94	55·4 — 70·8	64·05 ± 0·70	3 40
8·49	27	53·3 — 70·5	62·20 ± 1·50	3·90
—	62	52·1 — 73·8	63·21 ± 1 24	4 86
6 06	29	53·6 — 72·9	65·12 ± 1·60	4·32
8·28	79	55 5 — 71·2	64·68 ± 0·72	3·23
6·45	104	57·9 — 77·5	67·08 ± 0·74	3·74
7·68	55	59 0 — 73·5	64·69 ± 0 68	3 15

TABLE II. SIGNIFICANCE OF

Groups.	Maxillo-Alveolar Length	Maxillo-Alveolar Breadth	Palatal Length
S.E.A. Negro *vs.* Ovambo	Significant	Not significant	Significant
,, ,, *vs.* Batetela	Very significant	Very significant	—
,, ,, *vs.* Gaboon Negro	Very probably significant	Significant	Not significant
,, ,, *vs.* Bush	Very significant	Very significant	Very significant
,, ,, *vs.* Australian	Doubtful	Not significant	Significant
,, ,, *vs.* Chinese	Very significant	Probably significant	Very significant
Ovambo *vs.* Batetela	Very probably significant	Very significant	—
,, *vs.* Gaboon Negro	Not significant	Probably significant	Significant
,, *vs.* Bush	Very doubtful	Very significant	Not significant
,, *vs.* Australian	Very significant	Not significant	Very significant
,, *vs.* Chinese	Not significant	Not significant	Not significant
Batetela *vs.* Gaboon Negro	Very significant	Not significant	—
,, *vs.* Bush	Very doubtful	Not significant	—
,, *vs.* Australian	Very significant	Very significant	—
,, *vs.* Chinese	Doubtful	Significant	—
Gaboon Negro *vs.* Bush	Significant	Significant	Very significant
,, ,, *vs.* Australian	Significant	Significant	Probably significant
,, ,, *vs.* Chinese	Significant	Not significant	Very significant
Bush *vs.* Australian	Very significant	Very significant	Very significant
,, *vs.* Chinese	Not significant	Very significant	Significant
Australian *vs.* Chinese	Very significant	Significant	Very significant

DIFFERENCES BETWEEN MEANS.

Palatal Breadth	Bicanine Breadth	Maxillo-Alveolar Index	Palatal Index	Bicanine Index
Very doubtful — Doubtful Not significant Not significant Not significant	Very doubtful Very significant Very doubtful Significant Very significant Not significant	Significant Very significant Not significant Not significant Significant Very significant	Significant — Very significant Very significant Significant Probably significant	Doubtful Not significant Not significant Not significant Very significant Not significant
— Significant Significant Significant Significant	Very probably significant Not significant Probably significant Very significant Not significant	Not significant Probably significant Doubtful Very significant Doubtful	— Very significant Not significant Very significant Very doubtful	Not significant Probably significant Very probably significant Very significant Significant
— — — —	Significant Not significant Very significant Very significant	Significant Significant Very significant Not significant	— — — —	Not significant Not significant Very significant Doubtful
Not significant Not significant Not significant	Significant Very significant Not significant	Not significant Not significant Very significant	Very significant Not significant Very significant	Not significant Doubtful Not significant
Not significant Not significant	Very significant Very significant	Very significant Very significant	Very significant Very doubtful	Significant Not significant
Not significant	Very significant	Very significant	Very significant	Significant

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THE LEGEND OF LUKAS, THE " BABOON BOY ".

BY

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Read 1st July, 1940.

Early in 1939 Professor R. Ruggles Gates of King's College, London, requested me to enquire fully into the story emanating from various South African newspapers of a native boy supposed to have been nurtured by baboons. Professor Gates was at that time interested in the publication of a book by Professor Robert Zingg of the University of Denver, Colorado, giving an account of two " wolf children " of Midnapore in India about 1926, and forwarded a press cutting about the South African "baboon boy " from the New York Times of Sunday, 21 August, 1927.

Accordingly, last year I made a report to the Association about the documents I had received which appeared to support the contention that in the " baboon boy " Lukas of Shawpark, in the Grahamstown district, there was a genuine case of feral man in South Africa.

With the assistance of Mr. F. R. Paver and Mr. G. Makepeace of " The Star " a report on the newspaper side of the story was prepared, which showed that all the South African stories centred around this particular individual, the most complete accounts being those published in "The Star" of 4 October, 1930, " A native Romulus of modern times " by Ethelreda Lewis, and in "The Outspan" of 4 September, 1931, " The truth about the Baboon Boy " by George H. Smith.

Some people may remember that a native Ndola, who was exhibited publicly in Johannesburg in 1937 as a baboon boy, turned out to be a cripple, infantile paralysis having caused his four-footed gait. Despite the scepticism induced by cases of that sort, and which had inhibited me up to that time from taking any interest in the Lukas story, the statements secured from the boy himself and from Sergt. W. J. Coetzer and Lt. Col. O. J. T. Horak of the South African Police in the Cape Eastern Division indicated that the feral story might be true.

This was the position twelve months ago. After the meeting of our Association at East London I went across to Grahamstown and, after some difficulty, found the farm and the boy. I was not equipped with instruments for making a full enquiry but the inspection was adequate to elicit certain facts.

In stature and posture the boy, who is now apparently 45 or more years of age, is bushmanoid, a diagnosis corroborated by the form of his head and his facial features. When stripped and especially when he assumes the quadrupedal gait to demonstrate how he walked with the baboons, one is struck by the extreme slenderness of the loins, the marked lordosis of the lumbar region, the unusual anterior protrusion of the chest and the massive development of the dorsal spinal musculature. I found no sign of paralysis and the anatomical features were consistent with the story of early quadrupedal habits and I was prepared to accept the story provided subsequent investigation corroborated it.

I then referred the documents and my report to Dr. G. Dru Drury of Grahamstown and to Dr. J. A. van Heerden, Physician Superintendent of the Mental Hospital, Grahamstown, to enlist their assistance in following the matter up. They have taken infinite pains to go into the whole story, examining every available witness.* Immediately grave discrepancies emerged between the testimonies of various individuals relative to the details of the legend and the facts elicited from records. Dr. C. G. Cassidy of Kenilworth, C.P., examined the old records in the Archives relative to early admissions to the Mental Hospital at Grahamstown and found that Lukas, then said to be 13 years of age, a male coloured herd boy of Burghersdorp, had been admitted as the result of reports by Dr. H. Caiger and Dr. J. T. Bolger as a case of insanity subsequent on injuries to the head on 30 March, 1904.

The notes in the Archives revealed that Lukas had a 5″ semilunar indentation over the left side of the skull and a badly-united fracture of the left tibia, wounds that are still traceable to-day. The identification of the thirteen year old herd boy with the nearly fifty year old farm hand of to-day is therefore complete. In 1904, too, the records say that

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* The evidence has been published in more extended form by Robert M. Zingg in The American Journal of Psychology, July, 1940, Vol. 53, pp. 455-462.

Lukas, although "rather incoherent in his replies to questions," said the skull wound was the result of the kick of an ostrich.

Thus the records proved that the boy Lukas (or Lucas) was not caught amongst baboons at Koonap, Carlisle Bridge or Pluto's Vale, that he had the name he bears before ever the farmer Smith saw him and that he was not dumb when he entered the asylum. Further the injury, being situated in the vicinity of Broca's motor speech convolution and the motor area of the brain generally, could easily account for the incoherent speech and the motor defects, which apparently characterised the case when admitted.

Subsequently Drs. Dru Drury and van Heerden visited the farm, took measurements and further evidence there and at considerable expense they also arranged for his going to Grahamstown and being examined by X-rays. Dr. van Heerden found that his intelligence is that of a low grade imbecile and it was impossible to complete any standardised intelligence tests on him; he is unable to count to five, shows no planning capacity, has a total disregard of form or contour as shown by his handling of the Sequin board, and has no knowledge of money values. Meantime Dr. Dru Drury corroborated the data relative to the original head and leg injuries and attributed the muscular clumsiness still persisting to the combined effects of the accident and low intelligence. At the same time the careful examination of the numerous witnesses, that were still traceable, elicited no secure information of, but rather a wholesale uncertainty about or actual denial of the feral story.

The exhaustive examination carried out by Drs. Dru Drury and van Heerden, in which they have been so ably assisted by Dr. Cassidy, has failed to disclose any ratification whatever of a feral stage in the life history of Lukas, the so-called "baboon boy". They indicate rather that the legend arose through local gossip based on his general appearance and habits and possibly also through the expectation of gain arising from exploiting the possibilities of such a story.

The refutation of the legend of Lukas by the individuals concerned has thus proven untenable any of the stories that have hitherto been published about feral man in South Africa.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVII, pp.* 296-299.
February, 1941.

DIAS CROSS (PADRAO SAN GREGORIO)

BY

JOHN HARCUS,
29, Beaconsfield Avenue, Primrose.

Read 1st July, 1940.

The following notes form a corollary to Dr. Eric Axelson's narrative (this Journal 35: 417-429) of research, search and recovery of sections and fragments of the Dias Cross, its assembling and final cementing together, as related in a pamphlet of later date by Dr. Axelson.

In the two months spent in sorting the fragments and reconstructing the Cross, the following conclusions appeared inevitable:—

THE DEFACING OF THE COAT OF ARMS.

As in the case of the Padrão now in Germany, there is every probability that the broad rectangular section, immediately below the surmounting cross, once carried a carved coat of arms; possibly some decoration or inscription occupied the left and right sides of this prism, and the back may also have been inscribed.

In minutely scrutinising a bucket full of chips, from the size of a "tickey" to half-crown size, an assortment of about 200 pieces emerged, and were added to the larger carved pieces which were previously obvious as portions of the ornamentation or inscription.

The thinness of all this material should be noted, particularly the uniform thinness of all the smaller chips, the bulk of which are only ¼″ maximum thickness.

The largest ornamented fragment is a segment about 6″ x 1½″ x ½″ thick, and seems to be part of an encircling "garter" or ribband, with a buckle suggested. Three discoidal pieces each shows a scroll or volute, these fragments being about the size of a crown-piece and ¼″ to ⅜″ thick. Many thin fragments show stippling, and there are several skilfully made incised "full-stops," each on a tiny fragment

There are also a few portions of letters which had been incised into the marble as is the remaining inscription, and which have survived, in thin fragmentary form, the ordeal of being chipped off.

These significant fragments, set in plasticine on a small sheet of zinc, are in the care of Professor Leo Fouché.

All the material could have been divided into two groups:—

(1) Weathered and patinated.
(2) Sharp, and unpatinated.

(1) The material under the first head consists of:—

(a) All the large blocks which had been in the sea. patinated.
(b) The inscribed section, which is weathered only.

(2) Large and small fragments and chips.

(c) Hand-on-edge shaped and large hand-size, which have evidently been protected by sinking into dry sand, and remained sharp and fresh.
(d) All the small and minute chips, to fingernail size, recovered from the sand, remain sharp and fresh.

In all these thousands of small and large sharp fresh chips under (2) there is not a single sign of calcination nor, of course, on the (1) group.

It seems necessary therefore to discard any idea that the pillar was shattered by lightning.

After a careful study, in every possible light, of the faces of the rectangular block which had once carried the coat of arms and inscription, and the uniform thinness of all the small chips, it seems probable that the defacement was deliberately done by a craftsman who could use a mallet and chisel as a trained man would. The face of this block betrays, in a good light, that these tools have been used to drift off, in *regular diagonal alignment*, chip by chip, every vestige of the emblazonment and side inscriptions which proclaimed the origin of the beacon.

The significant fact emerges that the defacing *did not affect the general flatness of the faces despoiled*, nor seriously alter the *true rectangularity* of even one of the sides of the prism which had carried the coat of arms and inscription.

This fact alone seems to cut away the suggestion that an act of the elements could have so dressed off *four faces* and left them scarred *but flat* planes, still at right angles.

The other equally significant fact is the multitude of finger-nail sized thin chips.

These are plainly not the result of shattering: they are too uniform in size, in their thousands; too thin, minute, and, to a large extent, not on the lines of cleavage but obviously "lifted" off the various faces by regular calculated blows of a certain restrained strength,—a strength sufficient to remove the surface ornamentation and inscription, without challenging the solidity of the block of limestone. Possibly the first vandal ship was satisfied with this defacement.

Natives, or a later ship, may have thrown down the padrão at its site, shattering it, so that, while the greater proportion of it went over the cliff into the sea, a certain considerable fragment, which had two parallel faces 8½″ apart (Axelson's pamphlet) was left on the top of the cliff, and became buried in the sand.

As for the masses which fell into the sea, the wash of the waves and the encrustations of marine growths softened the scars of the chisel, but did not obliterate the betraying *diagonal regularity* of the strokes of the tool.

Had natives set out to destroy the coat of arms, they would have smashed and shattered the whole block into flat, hand-sized fragments, mainly breaking on the planes of cleavage, as the upper section of the lower pillar was, when found.

One cannot picture natives taking the trouble to chip painstakingly at the decoration, so that it came away in thin flakes and left the block still a fairly uniform, true-faced surface. Nor had they the tools.

The fell job was done by a craftsman, at least as skilled with a chisel and mallet as a ships-carpenter would be.

The motive may have been anti-catholic, or more probably simply prejudice against "foreigners," on the part of some visiting vessel of another nationality.

APPENDIX.

As regards the date of destruction of the padr*ao*, Dr Axelson writes as follows:—

"The padrão was certainly down by 1575, when Perestrêlo made his survey of the coast. It was probably down long before judging by the total lack of reference to it in early records. João de Lisboa (pilot to India between 1498 and 1525) in his pilot book talks about it as being still in existence, but that might be in reference to his earlier years of travel. There is evidence that French and Spanish ships were early on the coast, one in 1517, another in 1527."

I am greatly indebted to Dr. Axelson for kindly supplying the following data, viz.:—

(1) Antonio de Silveira to King of Portugal, July, 1518, from Moçambique:

Reports arrival at Kilwa of a French ship of about 250 tons, under the command of Santiago de Crasto.

Reports arrival in Moçambique of a dozen Frenchmen under João de Varamsano a Florentine. They are survivors of a shipwreck on Madagascar.

Demands regulations to prevent the arrival of French and Spanish ships in Moçambique waters.

(2) Sebastião de Sousa to King of Portugal, 17/9/1521, from Moçambique:

Hears that some Frenchmen have reached Madagascar.

(3) Baptista de Apaçora and Leão Pancado to King of Portugal, 25/10/1520, from Moçambique:

Describe their voyage: they are the master and the pilot of a Spanish vessel sent out by Charles V; description of journey via the East Indies as far as Moçambique.

South African Journal of Science, *Vol. XXXVII, pp.* 300-312.
February, 1941.

A PRELIMINARY ACCOUNT OF THE WONDERWERK CAVE, KURUMAN DISTRICT.

SECTION I: SITE AND ARCHAEOLOGY

BY
B. D. Malan,
Bureau of Archaeology, Johannesburg.

SECTION II: THE FOSSIL REMAINS,

BY
H. B. S. Cooke,
Department of Geology, University of the Witwatersrand.

With 5 Text Figures.

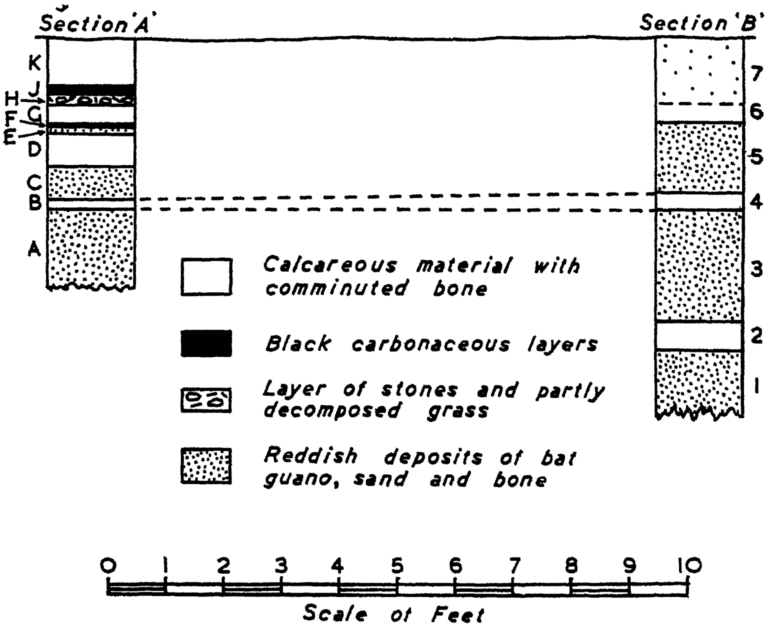
Read 1st July, 1940.

Section I.

Introduction: The Wonderwerk Cave has long been known as a site at which prehistoric rock paintings occur. It was first described by Methuen in 1846 but its importance recently became more apparent when the Bureau of Archaeology received from Mr. J. D. Malan of Blikfontein, a small collection of fossil bones and teeth. Included with this collection were a few human artifacts and in consequence of the interest of this association a preliminary inspection of the cave was carried out on the 16th May, 1940. It is proposed to conduct detailed excavations at a later date.

The cave is situated in dolomite, probably of the Campbell Rand Series, with a clearly defined dip of 15° to the east. It occurs at the base of a 400 foot conical hill a few hundred yards south of the homestead of the owner, Mr. N. J. Bosman. The farm takes its name from the cave. The entrance faces north and is approximately 50 feet wide. From the drip-line the opening runs southwards into the hill for a distance of 300 feet and then veers eastward for some 75 feet, when the back of the cave is reached. The rear portions of the cave are in complete darkness.

The roof is flatly arched, the walls being practically parallel and perpendicular. At the entrance the roof is about 15 feet above present floor level, but it slopes to about 7 feet where light fails. A few poorly developed stalactites are seen. The present floor of the cave consists of an extensive deposit of occupational material and bat guano. It is level until near the back of the cave where it appears to have sloped upwards slightly before disturbance by recent excavations for fertilizer. A single large irregular stalagmite stands in the centre of the light portion of the cave and reaches to about 8 feet above present floor level. Paintings, much obliterated by visitors, adorn both walls from the entrance inwards for a distance of about 60 feet, beyond which point the light fails.


Section 'A'
Section 'B'
K
J
H
G
F
E
D
C
B
A
7
6
5
4
3
2
1
Calcareous material with comminuted bone
Black carbonaceous layers
Layer of stones and partly decomposed grass
Reddish deposits of bat guano, sand and bone
0
1
2
3
4
5
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7
8
9
10
Scale of Feet

Fig. 1. Scale sections through the excavated area in the Cave.

A comparatively small area of the deposit has recently been excavated to a depth of some 4-5 feet for fertilizer, but the writer was informed that work has been discontinued on account of the disappointing results obtained. These excavations have left a vertical face of considerable length at the point where the cave veers to the east. As time did not permit of a complete record of the whole section being made, sections from two portions of this face were recorded and are shown in Fig. 1. The face reveals a number of layers, mostly well demarcated vertically and grading or disappearing laterally.

The deposit at this point contains only very few fragments fallen from the roof of the cave. A few feet to the east of Section A the face revealed a series of four well separated layers of dried grass and small stones. These appear to have been beds, though the reason for the stones is problematical. From amongst the grass of the topmost of these beds, some 6″ below the surface, was recovered a smooth, straight stick 14¾″ in length and of ⅜″ diameter, which may well be an arrow-shaft. The wood is well preserved and despite the dryness of the deposit cannot be of extreme age No fossils were found *in situ*. A heavy circular scraper of possibly Middle Stone Age character, made on a tabular fragment of chert was found in the lowest layer exposed at the time of the inspection, Layer 1 of Section B. Six flakes were recovered from the residue of the farmer's sievings, and their exact horizon in the deposit is therefore not known. The largest of these is 7″ in length, 1½″ broad and ¾″ thick, has a well facetted striking platform, and shows distinct features characteristic of the Levallois technique. Adhering to the chert of which the flake is made is a little deposit suggesting that it came from one of the reddish layers of bat guano. Two of the remaining flakes also show Levallois technique, and one of these has been utilised. A good "ordinary" burin showing several burin facets was also recovered. These specimens strongly suggest the occupation of the cave by people who were masters of the Levallois technique during Middle Stone Age times.

A fragment of a bored stone and an end-scraper of Smithfield type were found on the surface outside the cave and indicate the occupation of the cave also by Later Stone Age man. The end-scraper has been twice worked, and if patina can be trusted, may have been made by Middle Stone Age man and retrimmed during the Later Stone Age. Occupation of the cave in Later Stone Age times is confirmed by the presence of the paintings on the cave walls.

THE PAINTINGS: In the well-known Report submitted to the Cape Legislative Assembly in 1906 (C4 and C4A—'06) the following appears:

> "*Kuruman*: The only paintings known, representing the different local antelopes, are in a cave on the mountain side near the Koning Native Reserve. They have nearly all been destroyed, visitors having scribbled over and otherwise defaced them."

There can be little doubt that the site referred to is the one known as Wonderwerk.

The limited time available did not permit of the paintings being copied or of a detailed record being made. Many of the paintings have suffered through natural weathering, but far greater damage has been done by thoughtless visitors to the site. They show a variety of colours, styles and subjects, but with the exception of certain animals outlined in black, no polychromes occur.

The following examples were noted:

Dark red monochrome:	geometrical designs.
Black monochrome (superimposed over light red):	geometrical designs, "aprons", and water fowl.
Yellow monochrome:	elephant, antelope.
Red monochrome:	various animals.
White monochrome:	various animals, ostriches, eland, wavy lines and geometrical designs.
Red monochrome with black outline:	antelope.

The black monochrome and dark red geometrical figures were the most recent. They appear superimposed and are also better preserved than the other series. More detailed superpositions could no doubt be noted in the course of a fuller study.

ACKNOWLEDGMENTS.

The generous co-operation which Mr. J. D. Malan accorded to the Bureau of Archaeology was instrumental in bringing the site to our notice, and the writer is indebted to him for his donations and for accompanying him at the time of the inspection. To Mr. N. J. Bosman he expresses his thanks for permission to work and for his kind hospitality.

(B.D.M.)

SECTION II.

INTRODUCTION: A small collection of bone fragments and teeth sent by Mr. J. D. Malan to the Bureau of Archaeology early this year were handed to the writer for a report. An upper equine molar was provisionally identified as the extinct *Equus cawoodi* Broom and the remaining few as upper and lower teeth of the living *Equus burchellii* Gray. More material was requested, and some thirty broken bones and horn cores and forty teeth were soon received. This collection also included three artifacts and more of the large teeth of the extinct horse, and it was decided that the cave itself should be investigated without delay. A preliminary inspection of the site was carried out by Mr. B. D. Malan of the Bureau, whose account of his visit appears above. On his return he brought with him a further large number of bones, horn cores and teeth and the whole collection now comprises 43 bones, 23 horn cores and horn fragments and 173 teeth. All these came from only a comparatively small and shallow excavation and bear witness to the richness of the site. The precise distribution of the fauna in the deposit and the association with the implements is not yet known, but it appears probable that the bulk of the material is Later Stone Age and partly Middle Stone Age.

The bones are on the whole little impregnated but do show a certain amount of leaching and alteration. The teeth also are only mildly impregnated, though the larger equine molars appear more thoroughly petrified than the others. Two antelope teeth have been severely charred. Whether this has occurred recently or not cannot be ascertained. The anterior part of the lower jaw of a quagga is completely blackened though it has not been charred, and it may well have acquired its colour by burial in the black carbonaceous layers such as F and J (Section A, Fig. 1). The carbonaceous matter of these layers cannot definitely be ascribed to ash as microcsopic examination shows vegetable matter in a sufficiently advanced stage of decomposition to give the layer its character. Certain of the layers, notably layer 2, (Section B, Fig. 1) are crowded with small fragments of bat, bird and rodent bones, but in the samples collected no identifiable material was found. The greatest interest of the fossil remains lies in the equine teeth, and these will be discussed at some length. Apart from some of the equidae and with the probable exception of a very large antelope, the species represented are not extinct forms, but it is of considerable interest to record the entire assemblage. Identifications have been based on the horns and teeth only, as the numerous bones are of little classificatory value.

ORDER RODENTIA—FAMILY HYSTRICIDAE.

Hystrix africaeaustralis Peters: Two incomplete rami and an isolated tooth of the porcupine constitute the only recognisable rodent remains, but very many of the ungulate bones show evidence of the gnawing of these animals.

ORDER ARTIODACTYLA—FAMILY BOVIDAE.

Syncerus caffer (Sparrmann): The Cape buffalo is represented by a portion of the rugose base of a horn.

Peloroceras helmei (Lyle): There are in the collection ten teeth whose size equals or exceeds that even of the kudu or eland. In form these molars clearly belong to a member of the Alcelaphinae but exceed in size the largest wildebeest teeth known to the writer, and indeed, resemble the teeth of the hartebeest and blesbok rather than the gnu. Lyle (1931) refers a third upper molar " like that of a hartebees but very much larger " very tentatively to her species *Bubalis helmei*, which was created on horn cores. Van Hoepen (1932) placed this form in a new genus—Peloroceras. The present teeth may also be described as similar to the hartebeest but much larger and they are therefore also tentatively referred to Lyle's species since they resemble teeth from the Floris Bad site and this species appears to be the only one into which they might be fitted. Two lower teeth are shown in Fig. 2, in comparison with the corresponding molars of the hartebeest.

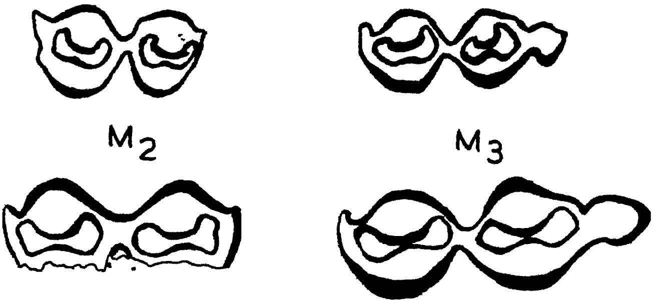

Fig. 2. Teeth of the large antelope (? *Peloroceras helmei*) compared with the corresponding lower molars of *Alcelaphus caama* (above).

Alcelaphus caama (Cuvier): This living harteheest is well represented by two almost complete horns and seven fragmental horns and cores. There are also seven typical teeth, two of which were used for the comparative drawings in Fig. 2, above.

Connochaetes sp. Eight wildebeest teeth occur in the collection, and there are also two horn fragments which probably belong to this genus.

Damaliscus cf. *pygargus* (Pallas): There are four teeth belonging to this genus, but the specific distinction is uncertain.

Antidorcas marsupialis (Zimmermann): The upper half of the horn of a female springbuck is present and a very worn pre-molar may possibly also be referred to this species.

Hippotragus sp.: Three teeth show the characters of this genus, but lack of comparative material renders specific identification difficult. No teeth of the historically extinct blaauwbok *H. leucophaeus* (Pallas) are available and both the Roan and Sable differ slightly from these teeth, though they are very near the latter species.

Taurotragus oryx (Pallas): Two excellent and almost complete horn cores of the eland are present in the collection, and there are also seven teeth differing very little from the living form.

FAMILY SUIDAE.

Phacochoerus cf. *acthiopicus* (Pallas): One warthog third molar occurs, but since it is practically unworn and incompletely erupted it cannot be distinguished with any certainty from *P. africanus*.

ORDER PERISSODACTYLA—FAMILY RHINOCEROTIDAE.

Ceratotherium simum (Burchell): The upper half of the slender anterior nasal horn of the white rhino represents this family in the collection.

FAMILY EQUIDAE.

As has already been mentioned, the major interest of the collection lies in the equine remains. It is astonishing to find that four species appear to be represented amongst the 119 molar teeth of this family. One of these is the living Burchell's zebra or Bontequagga, and one is the historically extinct Quagga, these two species comprising 102 out of the 119 molars. Of the remaining 17, twelve are at once distinguished by their great size, and the remainder are intermediate between these and the living forms. The enamel characters support entirely this rough classification on a size basis.

Equus burchellii (Gray): Seventeen upper teeth and sixteen lower teeth have been ascribed to this species.

Equus quagga Gmelin: Forty-one upper and twenty-eight lower teeth are referred to the recently extinct quagga. One front portion of a lower jaw and fragments of an upper jaw carrying incisors may belong to this species.

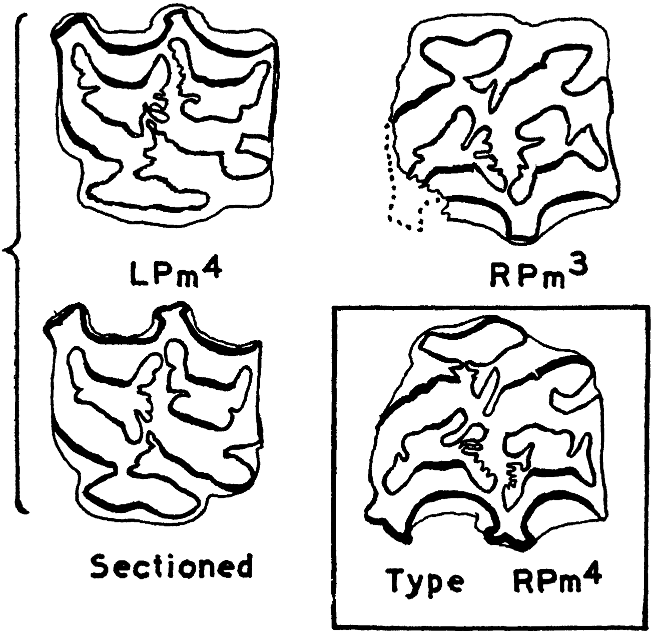

Fig. 3. Upper pre-molars of *Equus kuhni* Broom. The figure on the lower left is the sectioned surface of the little worn molar above; in the frame, the type molar of *E. kuhni* drawn from the original specimen.

Equus kuhni Broom: Two upper cheek teeth, a left fourth pre-molar and a right third pre-molar measure respectively 27·5 and 28·5 mm. across the enamel from protocone to mesostyle and are thus rather larger than the living forms. In enamel complexity they also surpass the living species and both in size and enamel characters resemble the type molar of *E. kuhni*. The styles are not grooved, but in the type this grooving does not extend very far down the tooth and may not be important. One remarkable feature possessed by these two teeth and by the type is the relative isolation of the hypocone. In the present fourth pre-molar the deep caballine fold of the type is lacking, though present in the third pre-molar, but the fact that the caballine fold is frequently absent in individuals of living species renders this of little importance. The fourth pre-molar is in a very early stage of wear (as also is the type) and its height is 77 mm. compared with 81 mm. in the type. The tooth has been sectioned 2·5 cms. below the grinding surface and a considerably simplified pattern is then exhibited as would doubtless also be the case if the type were to be cut. The two teeth, the enamel pattern of the sectioned surface and the enamel pattern of the type (drawn by the writer from the original) are shown in Fig. 3. It might be advantageous to designate the sectioned tooth a neotype of the species since it shows the simplified pattern consequent upon wear. Three lower teeth somewhat larger than those of the typical *E. quagga* may be lower teeth of *E. kuhni.*

Equus capensis Broom: There are five large lower teeth whose breadth over the enamel is 16 to 19 mm. and which correspond closely both in size and enamel pattern with the type series and neotype molar of *E. capensis*, and with the teeth described by Dreyer (1931) as *E. westphali* which Haughton (1932) referred to *E. capensis*. These teeth are shown in Fig. 4 together with the type series and neotype molar as figured by Broom (1928) and Haughton (1932) respectively. Broom's figure shows the protoconid and hypoconid as somewhat more rounded than they are in the actual specimen and the restoration of the metastylid is probably much too rounded. There appears, however, to be little doubt that these five teeth are *E. capensis* and the correspondence with the neotype is very close indeed.

There are also in the collection from the cave, seven upper cheek teeth which, in size, obviously correspond with the five lower teeth ascribed to *E. capensis*. Two of these teeth, a right second pre-molar and a left second molar are little worn and too brittle to section satisfactorily. The remaining five are shown in Fig. 5. Three of these teeth are in a correspondingly fairly advanced state of wear and are shown in their approximate relative positions, and a broken first molar of the opposite side may conceivably belong to the same dentition. The fifth tooth is a very little worn fourth pre-molar broken down its entire length so that only the fossettes and ectoloph portions remain. Its height is 91 mm. and its enamel pattern is considerably more complex than that of the other more worn teeth. In the form of the ectoloph and styles and in the degree of folding of the fossettes this tooth is very closely comparable with the little worn type molar of *Equus cawoodi* Broom (1928). The height of

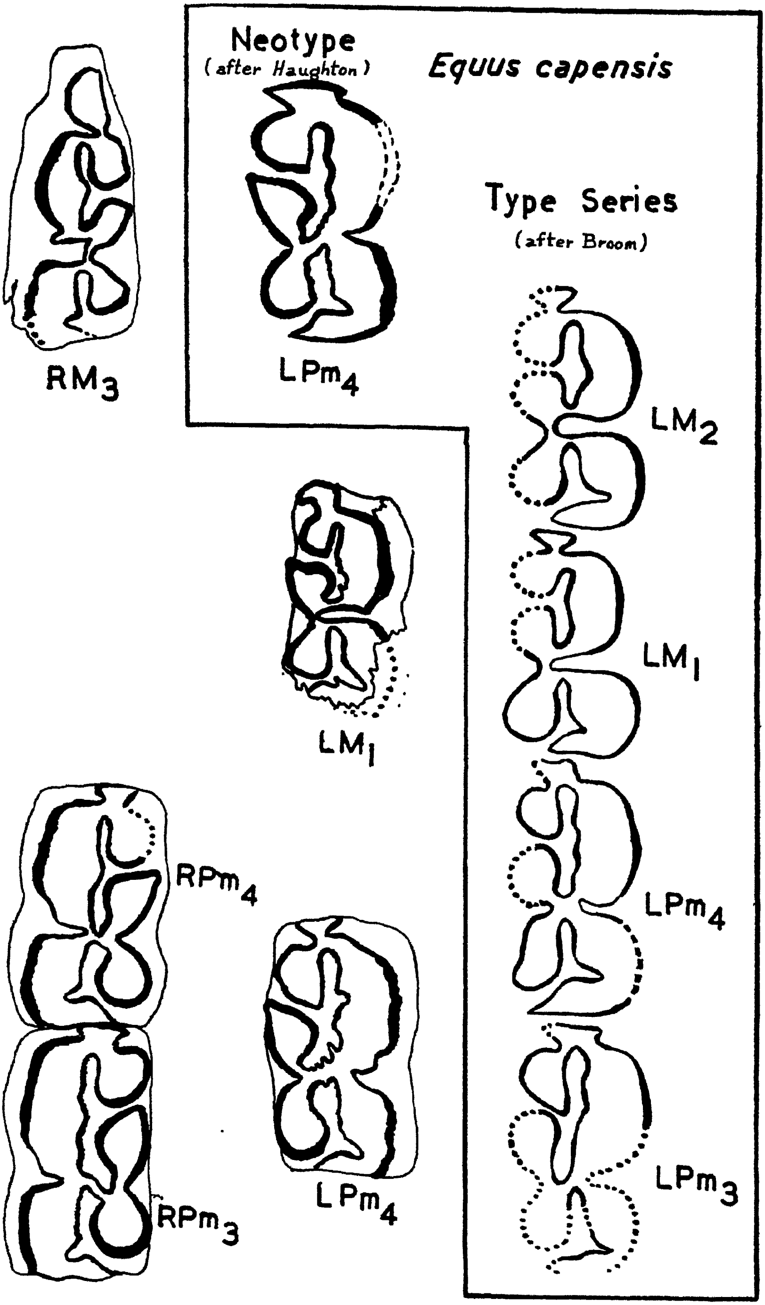

Fig. 4. Lower cheek teeth ascribed to *Equus capensis* Broom, and in the frame the type series and neotype for comparison.

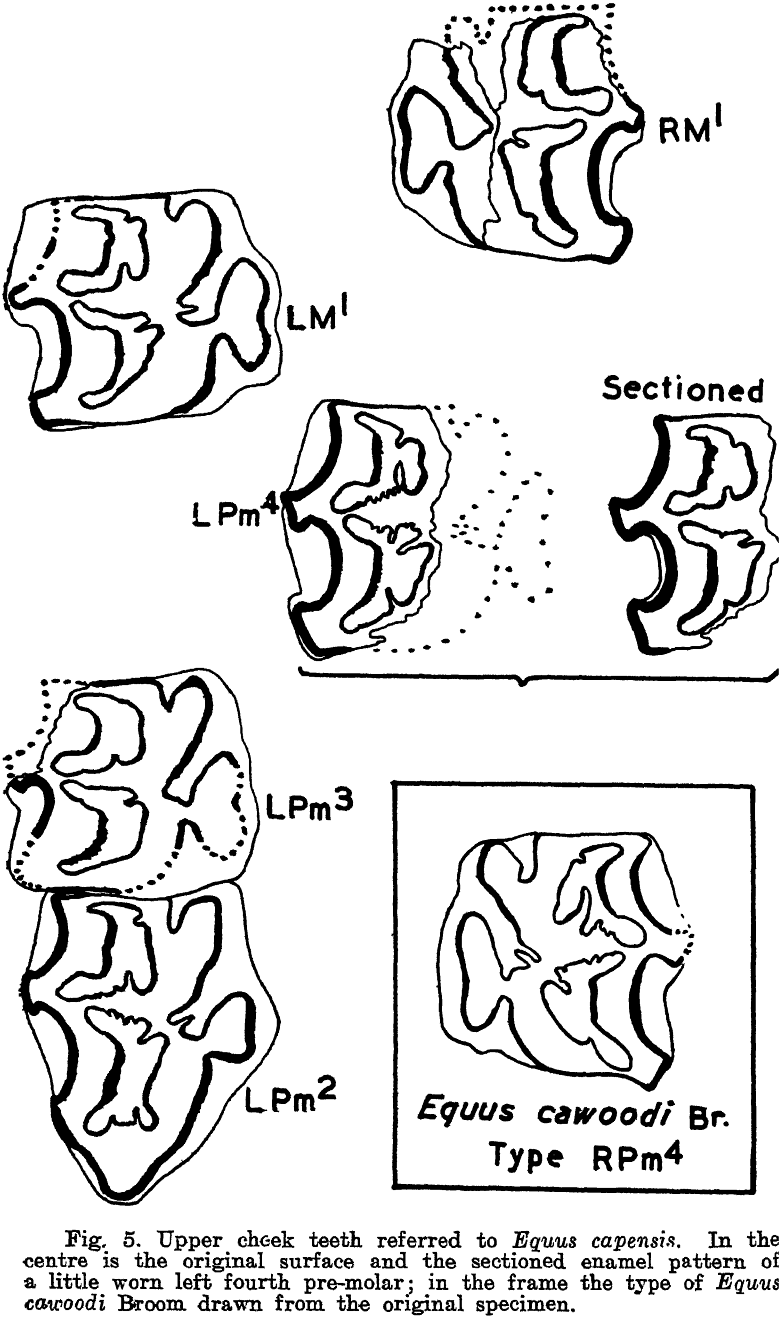

Fig. 5. Upper cheek teeth referred to *Equus capensis*. In the centre is the original surface and the sectioned enamel pattern of a little worn left fourth pre-molar; in the frame the type of *Equus cawoodi* Broom drawn from the original specimen.

this latter type is 78 mm. and its enamel pattern (drawn from the type by the writer) is shown in Fig. 5 for comparison. There can be little doubt of the identity of the broken molar with *E. cawoodi.* In order to ascertain the effect of more advanced wear on this tooth, it was sectioned at a height roughly corresponding to the state of wear of the other four teeth figured and it can be seen from the figured enamel pattern of this section that the complexity of the folding has been reduced to a degree comparable with that of the other four teeth. These upper teeth can therefore be said to belong with fair certainty to the same species, the simplified pattern being consequent upon wear. The only possibly significant difference between the type of *E. cawoodi* and these teeth is the slightly longer protocone of the type, though it may be noted that the protocone is commonly long in the fourth pre-molar of any species and is in living forms subject to a variation up to 30%. The upper teeth referred by Broom (1913) and Haughton (1932) to *E. capensis* agree with the present material very closely, and it would therefore appear that *E. cawoodi* represents merely a complex early stage of wear of the upper dentition of *E. capensis* and that the differences in complexity are due to varying stages of attrition and to the normal variation in complexity between pre-molar and molar teeth.

ACKNOWLEDGMENTS.

The writer is deeply indebted to Dr. L. H. Wells of the Medical School, University of the Witwatersrand, for his helpful readiness at all times to discuss various problems in connection with the identification of the material.

(H.B.S.C.)

SUMMARY.

The Wonderwerk Cave, which lies in the dolomitic limestone on the western side of the old Koning Native Reserve south of Kuruman, has yielded evidence of human occupation in Middle and Later Stone Age times. The walls of the cave are decorated with paintings and in the occupational material and bat guano which cover the floor of the cave to a depth of several feet, stone artifacts have been found. No human remains have so far been discovered, but a large number of fossilised animal bones and teeth have been removed. These remains include those of rhino, porcupine,

buffalo, wart-hog, eland, hartebeest and many other antelopes and also a large number of teeth belonging to four species of horse. One of these is the living Bontequagga or Burchell's zebra, one the historically extinct Quagga, and the other two are large extinct forms one of which is the giant *Equus capensis*. Discoveries of stone implements associated with fossils are very rare and this occurrence is one to which great scientific interest attaches.

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STUDIES ON A MUMMIFIED INFANT FROM PILGRIM'S REST.

I. The Technique of the Restoration of Mummified Tissues.
II. Anthropological Observations on the Specimen.

BY

L. STEIN.

Department of Anatomy, University of the Witwatersrand, Johannesburg.

Read 1st July, 1940.

South African Journal of Science, *Vol. XXXVII, pp.* 313-319.
February, 1941.

HUMAN SKELETAL REMAINS FROM THE MUMBWA CAVE, NORTH RHODESIA

BY

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Read 2 July, 1940.

The human skeletal remains discovered by the Italian Scientific Expedition in the Mumbwa cave, N. Rhodesia, during 1930, have so far received only very cursory notice (Dart and del Grande 1931). It has for some time been felt desirable that a further account of them should be given in the light of more recent studies which have amplified and clarified our knowledge of African physical types. This study is being presented at the present time in view of the supplementary excavations undertaken in this cave by Mr. J. Desmond Clark of the Rhodes-Livingstone Institute, Livingstone, N.R. Mr. Clark, although he has not succeeded in recovering any further identifiable skeletal remains, has furnished new evidence regarding the stratigraphy of this important site.

These human remains, though representing a large number of individuals from several different horizons, are for the most part extremely fragmentary; the most complete specimens are the three partial crania from Stratum IV (150-175 *cm.*, not mm. as misprinted in the report). These will therefore be described at the greatest length, followed by a consideration of those fragments from other horizons which display marked diagnostic features. The principal criteria upon which this study is based are summarised by Galloway (1937a).

Description of Material.

Skull IV. 1: This definitely fossilised calvaria consists of parts of the frontal, parietal and occipital bones of an elderly individual, the coronal and sagittal sutures being almost obliterated. Although the supra-orbital margins are wanting, it is apparent that the braincase was of only medium length; it is very narrow and appears to have been low-vaulted. In these respects, as in the flattened vault, marked post-coronal groove, slightly projecting occiput and depressed course of the parieto-squamous suture, it suggests the Bush type. From that type, however, it differs conspicuously in its ellipsoidal contour, with total lack of parietal bossing, also in the great breadth of the frontal region relative to the parietal and in the gradual curve of the forehead into the vault. Among other features, the external occipital protuberance is remarkably large and prominent, although the superior nuchal line is but faint; there is considerable hollowing of the upper part of the nuchal surface. The indistinct temporal lines end in a blunt vertical ridge above the hinder end of the parieto-squamous suture, which clearly was continuous with a prominent and sharply upturned supra-mastoid crest upon the temporal bone. Behind this ridge the supra-asterionic region is distinctly hollowed. The cranial bones, massive in proportion to the size of the skull, are marked internally by broad but not very deep meningeal grooves.

In this specimen there is thus a peculiar blending of features. While the dimensions and most of the lesser non-metrical features are Bush or at least pre-Negro, the ellipsoidal cranial form and the frontal contour imply an admixture of some type with definitely adult, in contrast to the infantile Bush, cranial characters.

SKULL IV. 2: Of this specimen numerous fragments of the braincase and face, as well as the nearly complete mandible, are present, corresponding in preservation with the former specimen. The only evidence of the age of this individual is the complete eruption of the wisdom teeth.

The cranial bones, extremely thin even for an adolescent, are both fragmentary and somewhat warped, so that measurements of the braincase are of little value. Certain features are however clear. The frontal region is foetal in character, the low, narrow forehead overhanging a flat glabella and extremely faint superciliary eminences; the external angular process forms a broad convex triangle without much lateral projection. Posteriorly the occiput is markedly projecting, the external occipital protuberance and nuchal lines extremely faint, and the nuchal surface indistinctly concavo-convex. A surviving portion of an occipital condyle is boldly convex and faces as much laterally as inferiorly. The temporal bone has the depressed upper margin indicated in the preceding specimen and the supra-mastoid crest, though relatively faint, has the bold upward sweep there prognosticated. It is separated by a broad shallow groove from the short, broad and flattened mastoid process, whose outer surface bears an indistinct ridge for the sterno-mastoid muscle. A slender tympanic plate surrounds the external auditory meatus, and in front of it is a deep but broad glenoid fossa. There are indications of both temporo-sphenoidal and inferior frontal eminences.

Enough of the face is preserved to show that it is small, slenderly built and orthognathous. The orbit is relatively large, with slender margins and a very oblique axis; the bridge of the nose must have been very flat, and its aperture is broad (platyrhine) with an indistinct lower margin. Below the orbit the zygoma and maxilla are very slender. There is a distinct infra-orbital excavation. The subnasal region is very short, due in part to the loss during life of all four upper incisors. Their absence in an individual whose upper cheek teeth and whole lower dentition were present at the time of death suggests the possibility of deliberate removal. The palate appears to have been short, broad and moderately deep.

The mandible is complete except for the right ascending ramus and left condyle. Those parts which are present conform generally to the description of the Bush mandible given by Schepers (1934), but show certain differences indicative of a more pedomorphic character (Schepers 1935). Many teeth have been lost after death; those which remain are small and heavily worn. The wisdom teeth are very much reduced in size.

This individual is thus dominated, even more than the former, by characters which are pre-Negro and for the most part definitely Bush.

Fragments Associated with Skull IV. 2: Accompanying the fragments of this skull are a portion of the temporal bone of a second individual and some pieces of the shafts of limb bones. All are in the same state of preservation as the skulls already described. The temporal bone shows the remains of a small mastoid process, a prominent rounded and upcurved supra-mastoid crest, and a slender tympanic plate whose relation to the glenoid fossa is the same as in the Boskopoid skulls from Zitzikama (Gear 1926). On the medial aspect the grooves for the meningeal artery and the sigmoid sinus are deeply entrenched. This bone is therefore frankly Boskopoid in its preserved features, closely resembling the Zitzikama remains. The limb fragments are so gnawed by rodents that no conclusions can be drawn from them.

SKULL IV. 3: This skull differs conspicuously from the others both in preservation and in its physical features. It is in a considerably fresher state and clearly belongs to an appreciably later time horizon. Although the field diagnosis as a Bush type appeared justifiable from the slenderness and various structural features of the cranial bones, reconstruction has drawn attention to other and more problematical characters.

Of this individual the greater part of the braincase is present, but the face is represented only by the nasal bones and portions of the maxilla. The remains are those of a young adult, the vault sutures being open although the third molar tooth is erupted; there is no distortion.

The braincase is remarkably elongated (length 200 mm., breadth 125 mm., index 62·5), and its height, though only moderate in proportion to the length, greatly exceeds the breadth. Viewed from above the skull is ovoid; the frontal breadth almost equals the parietal. In a side view the forehead can hardly be distinguished from the vault, the two merging in a gentle curve which extends through bregma to a vertex situated just behind the plane of the external auditory meatus. From this point the contour descends by an equally gentle curve into the very prominent occiput. The external occipital protuberance and superior nuchal line are moderately developed; the nuchal surface is slightly sigmoid.

Though the mastoid process must have been relatively long, it is narrow, leaving the digastric fossa exposed posteriorly. There is a very prominent supra-mastoid crest, but the posterior root of the zygomatic arch is surprisingly slender for the size of the skull. The tympanic ring also is slender, while the glenoid fossa is deep but extremely wide. Temporo-sphenoidal and inferior frontal eminences are slightly indicated.

Viewed from the front, the glabella and superciliary ridges are moderately developed. They are continued by slender, rounded and everted orbital margins into the long narrow external angular processes. The interorbital region is remarkably broad, and the bridge of the nose flat; the nasal bones however project boldly forward, having a concave profile. There is a sharp sill to the inferior nasal margin, and the subnasal part of the maxilla is extremely short. From the remains of the palate it is clear that it was shallow, but its form cannot be estimated. The incisor teeth have been lost after death; the molars are small and not heavily worn.

This skull cannot in the total of its characters be identified with any definite type. Its great length suggests comparison with some of the long-headed pre-Negro skulls from South Africa. However, though many of its features would not be out of place in such skulls, others, notably the frontal and nasal profile, have no counterpart in them. In these features it might be compared with the Negro, but it is widely different from that type in other respects. While there are superficial resemblances to some of the ancient long-headed skulls from East Africa, and even to some European skulls, these will not bear close analysis. It appears possible to conclude only that this skull belongs to a mixed type, in which pre-Negro characters are mingled with others whose source is at present obscure.

REMAINS FROM STRATUM V.: These heavily fossilised fragments represent several individuals. Some of the cranial fragments are thick and massive, others more slender. Two portions of occipital bones are Boskopoid in contour, showing a massive occipital torus overhanging a deep transverse nuchal groove; a frontal fragment of moderate thickness indicates a relatively abrupt transition from forehead to vault. Among the limb fragments, a small delicate clavicle, if adult, must have belonged to an individual of Bush type. The lower end of a humerus is of moderate size; it displays a large supratrochlear foramen, which though found sporadically in all races is particularly frequent in the Bush type. Thus the few definitely identifiable characters of these remains are pre-Negro, belonging either to the massive Boskop or the small Bush type.

REMAINS FROM THE TOMBS OF STRATUM III.: The badly corroded hinder portion of a calvaria from tomb A is definitely fossilised and of slender structure. In its parietal bossing and in the contour of the occiput it approaches the Bush type, but the vault forms a higher curve both longitudinally and transversely than is usual in Bush skulls. Associated with this calvaria are the extremely corroded remains of a mandible containing heavily worn molar teeth.

In size and in such structural features as are detectable this is of Bush character.

Tomb B produced a number of definitely fossilised cranial and other fragments representing more than one individual. A frontal fragment displays a massive glabella and superciliary ridge associated with prominent frontal bossing; this "Australoid" complex of features may be ascribed to the massive pre-Negro or Boskopoid type. An occipital bone also reveals the features of this type as seen in those from Stratum V. Portions of two humeri are present, one being of medium size, the other long and massive.

Remains from the Uppermost Strata: These are consistently fragmentary, eroded and gnawed by rodents. They represent a number of individuals and differ considerably in their degrees of mineralisation. Very few fragments show clearly identifiable features. A heavily fossilised portion of a temporal bone shows a mastoid process and supra-mastoid crest closely similar to those of Skull IV. 3; another resembles more closely that of Skull IV. 2. Among the less mineralised fragments is part of a mandible with a very high coronoid process and deep sigmoid notch, therefore not Bush. There are also portions of an extremely slender clavicle and of a massive radius.

Discussion.

While these remains undoubtedly range over a long period of time, the majority are appreciably fossilised and must be of considerable antiquity. All of these ancient specimens display features of the pre-Negro types of southern Africa, Bush and Boskop. The discovery of these physical types in a stone age environment in Northern Rhodesia is in accordance with expectations. Both types extended considerably further to the north; Galloway has described (1933) an unmistakeable Bush skull from northern Tanganyika, and has pointed out (1937 b) affinities with both the Bush and Boskop types in crania found even further north. That these two physical types are related is obvious but their precise affiliation still remains obscure. In southern Africa the Boskop type makes its appearance earlier than the Bush, but it is not possible to assert definitely that this was the case at Mumbwa.

Even in the heavily fossilised skull IV. 1, however, there are physical features which do not belong to either the Bush or the Boskop type. The more recent skull IV. 3 shows an even more conspicuous, not necessarily identical, intrusive element. At present it is impossible to identify these elements with certainty; we may hope that future discoveries in Northern Rhodesia will afford a solution to these problems.

SUMMARY.

The skulls and other human bones described were excavated by the Italian Scientific Expedition in 1930, and were the first remains of man belonging definitely to the Later Stone Age to be discovered in Northern Rhodesia. The material consists of fragmentary remains of a large number of individuals, most of which are appreciably fossilised. The determinable physical characters of these remains are principally those of the Bush and Boskop types as found in the later Stone Age in South Africa. Certain skulls, however, show the intrusion of other elements which have not yet been identified.

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BORED STONES IN NYASALAND

BY

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Read 2nd July, 1940.

It has always struck me as being rather odd that bored stones of similar sizes and shapes should be found in such profusion in the Union of South Africa (Ref. No. 1) and in the Belgian Congo (Ref. No. 2) but not in the intervening spaces. Relatively few have come out of Uganda, Kenya (Ref. No. 3), Tanganyika and the Rhodesias (Ref. No. 4). Leakey completed ten years of intensive fieldwork before he found his first at Gilgil in the Great Rift Valley during our joint expedition in Kenya in 1937. Similarly, Wayland worked for many years before he found his first bored stone in Uganda. They have been found in West and North Africa (Ref. No 5), in Tibesti and elsewhere in the heart of the Sahara (Ref. No. 6) and in the Valley of the Nile (Ref. No. 7), but here again they cannot be said to be nearly as common or as varied as they are in the Belgian Congo and the Union.

Outside the Union, the richest known areas in the territories referred to seem to be the basins of the Ituri and Lualaba (i.e. the extreme north-eastern and south-eastern districts of the Congo), the slopes of Mount Elgon (both in the eastern districts of Uganda and in the western of Kenya), along the shores of Lake Victoria, and in the area between Lake Bangweulu and the Muchinga Mountains in Northern Rhodesia.

The Congo specimens, like those from the Union, include a great variety of shapes and sizes: spheroids, oblate spheroids, ellipsoids of revolution (about the minor axis), ellipsoids, disc, cube (with rounded edges), etc. (Ref. Nos 1B and 2). In both areas they occur with Neolithic elements. These are much more marked in the Congo where bored stones and ground and polished axes have frequently been found together—especially in the vicinity of the Kilo Moto Mines in the Ituri basin. Also in Kenya and Northern Rhodesia, bored stones and ground neolithic-type axe-heads have been found side by side, but it is impossible to say whether they represent elements of the same material culture or not. My field notes that refer to the discovery of a bored stone at the Gilgil river road bridge near Gilgil station on the Gilgil-Thompson's Falls road, read (21.4.1937): "Surface site: recovered portion of polished axe, pounders and grinders, grind-stone, bored stone (in quartz; entirely artificial), pottery (simply decorated before baking), many side and end-scrapers—the implements cruder than but the whole something like Smithfield B." Assuming that the various elements recovered were representative of the industry of the site, it was not possible at that time to describe the culture to which they belonged. Subsequent research however, suggests that it is possibly the Njoroan. Similar discoveries have also been made in Nigeria where small quartz pebbles (again ellipsoids of revolution about the minor axis) are found side by side with ground and polished axe-heads (Ref. No. 8).

No doubt our lack of knowledge about the distribution of bored stones generally and the various types particularly is to a large extent due to the difficulties encountered in field work—more especially in the Sahara and the equatorial forest regions where the country is heavily blanketed. Fresh discoveries are therefore always very welcome and it is for this reason only that I have undertaken this note.

One of the staunchest supporters of the Bureau of Archaeology is Mr. Rodney C. Wood of Livingstonia and Monkey Bay in Nyasaland. Among his recent donations are six bored stones which are worthy of note (Fig. 1). They are so far as I am aware, the first to be recorded from Nyasaland. The dimensions of the six in inches, their weights and the material of which each is made are given below. The dimensions are in the order: (A) maximum external diameter, (B) maximum thickness, and (C) diameter of the bore at the waist of the hour-glass perforation. The materials were identified by Mr. H. B. S. Cooke of the Department of Geology at the University of the Witwatersrand.

Specimen	A.	B.	C.	Weight		Material
				lbs.	ozs.	
NN 1:	5.2	1.7	0.8	1	14	Serpentine rock
NN 2:	4.4	3.2	0.9	2	2	Amphibolite
NN 3:	5.5	1.6	1.0	2	10	Amphibole-mica schist
NN 4:	5.6	1.7	0.5	2	1	Quartz-mica schist
NN 5:	?5.2	?1.4	1.0	?	?	Sericite-schist
NN 9:	4.3	2.2	1.4	1	12	Amphibolite

Two of the specimens (1 and 4) are natural water-worn pebbles, the only artificiality of which is the typical hour-glass perforation. The remaining four are artificially shaped throughout. No. 5 is fragmentary and the measurements given for the external diameter and thickness are estimates based on reconstruction. An estimate of weight serves no purpose. No. 2 is the Congo *casse tête* or ellipsoidal type, measuring 4·4″ along the major axis and 3·2″ along the minor. The remainder vary between the oblate spheroid or *sphéroid aplati* and *disque* types. With the exception of the "hammer-head" (No. 2) all the types occur in the Union in association rather with the Kitchen Midden and Wilton Cultures than with the Smithfield. Although the shapes and sizes of Smithfield specimens vary considerably, the great majority that belong to this Culture are oblate spheroids, i.e. the *sphéroid aplati* of the Congo; the well-known *kibi* or "Bushman digging-stone." On the other hand, the great majority of specimens found in our coastal Kitchen Midden and Wilton sites incline more generally to the ellipsoid of revolution or disc: circular in plan and comparatively flat in section (Ref. No. 9). This may be due to the fact that the makers of tools of the Wilton and Coastal Kitchen Midden Cultures invariably selected naturally water-worn pebbles for their bored stones. At the coast, these incline to the muffin-shape. Indeed it should be emphasised that the difference between the action of waves both at the sea and along the shores of large lakes on the one hand and that of running water on the other is to wear pebbles down through the ellipsoid of revolution to the flat muffin-shape in the former set of circumstances, and to the spheroid or oblate-spheroid or bun-shape in the latter. Naturally rounded stones selected along the shores of the sea and of lakes will therefore generally tend towards the disc and muffin-shapes, while those selected from river deposits will more often tend towards the oblate-spheroid or bun shapes. The Nyasaland specimens Nos. 1 and 4 may be on water-worn pebbles collected along the shore of Lake Nyasa.

Up to the present Mr. Wood has recovered nine specimens. "They come," he says, "from an area which may be roughly indicated as: the hill valleys north and west of the high mountain range known as the Nyika, at the base of the main ranges in Nyasaland territory. Also one from near Ekwendlini in Angoniland just north of Mzimba. Without exception all have been found by villagers hoeing gardens and I have details of the exact spot and finder of each stone.

The northernmost localities are in the Karonga administrative district but so far I can get no trace of any along the Lake shores or east of the main Nyika range between the south Rukuru river and the Tanganyika border. So far no other kinds of stone artifacts have come to light, but I feel that they must exist and hope to get on the track of some ultimately." This was on 1st November 1939. Since then Mr. Wood has had the luck that all pioneers deserve.

Of each particular specimen, Mr. Wood says:

" NN1: Found on surface near an old village in Ntariri district, North Nyasaland. This area is on the west side of the great Nyika Plateau mountain itself.

It was being used as a " charm "—probably associated with fertility or rain rites—by its finder.

NN2: Hammer shaped. Found in 1938 by villagers when hoeing a garden near the BaSukwa village of Muwofi in the Masuku area of North Nyasa. They believed its use was " to bring rain."

NN3: Found in 1939 by a boy herding cattle at Khonkuwe about 12 miles east of Ekwendeni, Northern Angoniland in Mombera's district, Nyasaland. Lying on surface in a bare patch in the sparse woodland around.

NN4: Found by villager of Terere village in district of Ntariri, North Nyasa, when hoeing his garden near village in 1938.

NN5: Found on 29.3.1939 by man hoeing his garden near Terere village at a place called Chikururu in Ntariri area, North Nyasa.

NN9: Found in January 1940 by a villager of Muwofi village in Misuku area of North Nyasaland when hoeing a garden on bank of the Songwe river. Was below surface. Turned up by hoe."

Mr. Wood's references to the use of certain of these specimens as charms, " probably associated with fertility or rain rites," is interesting in that Bantu-speaking people are known or suspected to have done the same thing in other parts of Africa, both in the central and southern regions.

They are not known to have made them but merely to have made use of them. The only part of the continent where Natives are suspected to have made bored stones themselves is in the Eastern Transvaal and Swaziland where many large and roughly chipped specimens occur in old terraces and areas set aside for gardening—especially in the Komati valley in the Carolina district. Here we have traditional evidence that these stones were used as " make-weights " on wooden hoes as shown in the accompanying sketch—Fig. 2. These specimens average about 7 ins. in diameter and 8½ lbs. in weight. But for this exception all the bored stones found in Southern Africa and elsewhere in the continent are associated with the last phases of the Stone Age: the Capsian of the North, the Magosian of Uganda (Ref. No. 10), the Smithfield, the Wilton and the Kitchen Midden Cultures of the South. In the case of the Eastern Transvaal (BaPedi) specimens, the Natives may in the first instance have used the bored stones left by their prehistoric forerunners, and in the course of time have copied and used them in the manner indicated—just as many Europeans to-day use them as door-stoppers or as weights to keep the rope of a head-stall taut.

The specimen illustrated in Fig. 2 belongs to the Iron Age but according to BaPedi tradition it was used in the manner illustrated only when iron hoes were not procurable. The hoe was made by an old Native in Sekukuniland and may

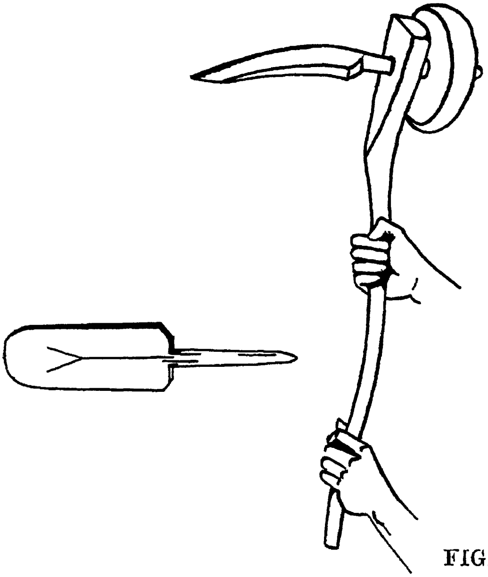

FIG. II.

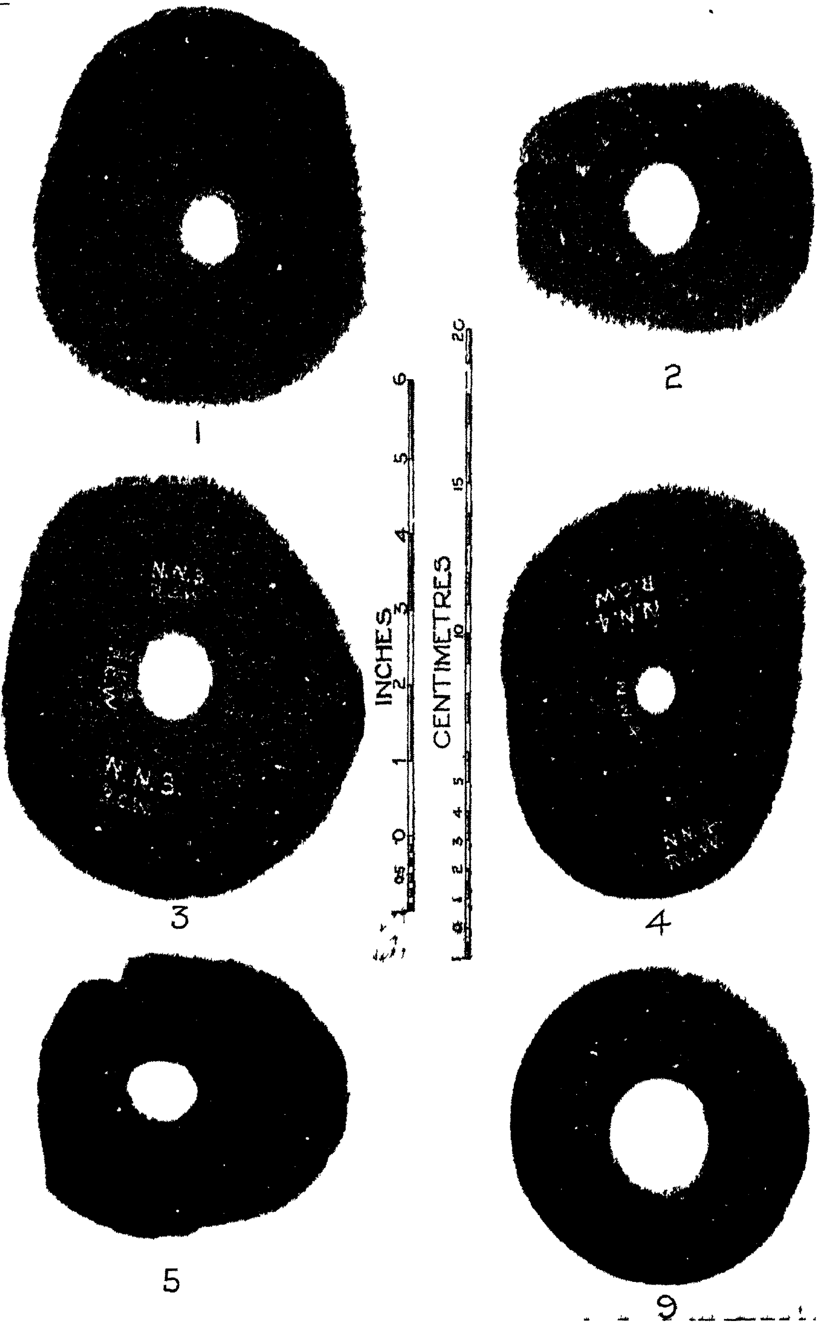

Fig. 1.

be seen in the museum of the Bureau of Archaeology. The bored stone is quite distinct from those found in association with the Capsian, Magosian and Smithfield cultures and altogether unlike the lighter and flatter specimens more generally associated with the Wilton and Kitchen Midden cultures.

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ANOTHER STONE AGE INDUSTRY FROM WEDZA DISTRICT S. RHODESIA.

BY

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INTRODUCTION.

In 1938 I wrote a short account of a surface site situated on the Land Settlement Estate, Wedza (Proc. Rhod. Sc. Assn. 1938: 153). The material used was dolerite, and the type artifacts were large prepared cores, and some rather indefinite hand-axes, some of which were of cleaver form. In addition there were rough flakes, blades, scrapers and possible burins. I then imagined I had discovered an Early Stone Age factory site, and I used the term Lower Palaeolithic to describe the industry.

Since then I have been working on a new site some 20 miles south of the first, near the Sabi river. Here I obtained an industry similar to that which occurred at the Land Settlement site, but with a very much richer supply of implements.

The purpose of this paper is to describe this new site and its contents, but it must be understood that the site is by no means thoroughly explored, the war having temporarily prevented further work.

This new material, however, affords evidence that the material from the Land Settlement Estate is not Lower Palaeolithic.

DESCRIPTION OF SITE.

The rough map gives the position of the site in relation to the river system and Wedza mountain.

The surrounding veld consists of thin bush and vlei, with a few thickly bushed kopjes dotted here and there. The ground slopes gently towards the Sabi river. Though really a granite country, in this particular area there is a fair amount of dolerite, and the kopjes are often composed of a mixture of the two rocks.

The site to be described is situated about 300 yards from the Sabi up a tributary named Umvura Chena. This stream has cut a deep channel as it nears the main river, and at one point cuts through a dyke of dolerite which forms large boulders in the bed of the stream and on the banks. It is on and near this dyke that the industry occurs. Artifacts are found on both banks, but the east bank has been the centre of activity.

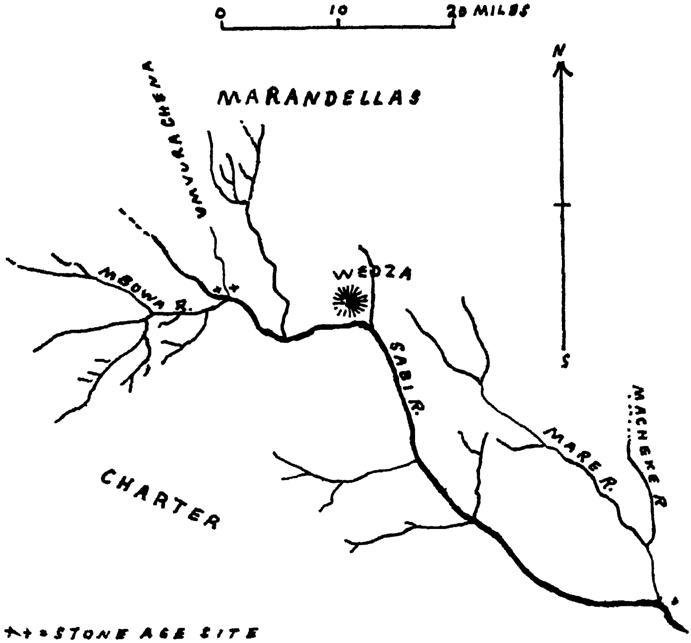


FIG.1

The site is not large, and is contained within an area of about half an acre, the richest part being on and close to the dyke where it slopes down into the stream. Here are piles of waste flakes with hammer stones and cores apparently lying in the very positions they occupied when the site was vacated. Some of the material is covered by a few inches of earth, and erosion appears to be taking place. I do not think the whole of the dyke has ever been completely covered. It is noticeable that tools found on the ridge are always very much more weathered than those found in the hollows where they are often half buried.

Tools of a Rhodesian Still Bay or Upper Bambata industry are scattered among quartz gravel at a point where the dolerite material thins out. These are described later. The quartz gravel in which they are found does not appear to have been deposited by river action, though a few water-worn pebbles occur. This gravel is similar to that which seems to be spread over the whole of the adjacent country. It is usually some inches below the surface but often exposed to erosion.

MATERIAL AND WEATHERING.

Dolerite has been used throughout the main industry. When fractured it is dark blue in colour.

All artifacts are weathered to a greater or lesser extent, and various stages of weathering often occur on a single specimen. A tool half buried is invariably more weathered where it has been exposed to the air. Therefore it would be impossible to rely on this factor as a means of dating.

The least weathered implements are light grey, those which have been more exposed are ochreous, reddish or dark grey.

DESCRIPTION OF IMPLEMENTS.

Though the core tool was the predominating element, it was often made from a flake, and flakes were used as scrapers.

Flakes were frequently detached from unprepared chunks of rock, but they were also produced by a very crude kind of Levallois technique. The cores, which are nearly always large, are roughly spherical, tending sometimes to the pyramidal. The striking platform is extremely simple, and has been formed by vertical trimming which consists of two flake scars When struck the core is more or less split in half, and the resulting flake is clumsy and humped in appearance. No. 4, Plate 1 figures a struck core with a prepared striking platform at both ends, A and B. No. 3 Plate VI appears to be a flake which has been worked round the edges, but the original core trimming still remains. The reverse face is a slightly trimmed flake surface. No. 2, Plate VI is a similar flake worked on both faces to form a chopping tool.

Small cores exist, but they are not common, nor have I any which show a satisfactory major flake scar, but the presence of small flakes with facetted butts is sufficient proof. In all cases the striking platform consists of two facets.

There are a few artifacts which may be regarded as blades rather than flakes, they are usually triangular in cross-section, and have plain butts.

Whether any of the small flakes and blades were ever worked up into definite tools is doubtful. Signs of use on the edges is rare, and in many cases may be of later date than the original flake. This will be discussed later.

Resolved secondary trimming is the rule on hand-axes and to a certain extent on scrapers.

Hand-axes: These appear to be of three types (a) Round ended, (b) pointed, (c) cleaver or tranchet. Other forms occur which are rather indefinite.

(a) The best of these are broken, this probably occurred during manufacture. Nos. 1, 2, 3, 4, Plate III are some examples. No. 1 has one face curved and the reverse face trimmed flat. One edge terminates in a flat unworked platform which is the original side. This is a common feature, and in some unbroken specimens the whole of one side has been left untrimmed. Nos. 2 and 3 rather resemble the tips of giant points, they are worked over both faces. No. 4 appears to be the butt end of an ovate. The edges of all the above tools are sharp and even, and secondary trimming of resolved type has been used. No. 2, Plate V, is the most complete of this series. It is worked over both faces, and the edges show resolved secondary work, a very celt-like object. It is not possible to say if any of these were made from flakes. No. 3, Plate 1, may be in the course of manufacture. It is apparently made from a flake. One side and the tip are trimmed to a fine edge. The other side is untrimmed except for about an inch near the apex. Flaking on both faces is confined to near the edges, a central area is unworked. The butt has received little attention. In No. 5, Plate III, a central ridge has been formed by flaking from the sides. The edges are ill defined, and the butt has not been sharpened. The top end has been trimmed on both faces to form a cutting edge. The reverse face is a flake surface. No. 2, Plate II, is similar in that it has a central ridge, sides roughly trimmed, butt square, and top end trimmed on both faces to a cutting edge. The lower face is a flake surface. These two tools perhaps belong to group (c). No. 5, Plate IV, is also made from a flake. There is little flaking except near the edges, which have received careful secondary trimming. Pecking occurs on one face, this has formed a small hollow, and was executed before the tool became weathered to the extent it is now. Flakes and slices of dolerite with a rounded end formed by resolved flaking, sometimes with the addition of a worked edge are very common.

(b) A rare tool. Nos. 1 and 4, Plate VI, No. 1, rather resembles an Early Stone Age hand-axe. The reverse face is only partly worked, and appears to have been a flake surface. This tool is the only one of its kind. No. 4 is made from a slice of dolerite, and only worked on one face.

(c) These tools are common, and they do not conform rigidly to one pattern. Some approximate towards the Early Stone Age type of cleaver, others have their cleaver edge rounded, and much retouched. They also vary much in size. Nos. 3, 4, Plate VII, and No. 3, Plate V, are examples of the former type, and No. 2, Plate VII, and No. 1, Plate 1, are examples of the latter type. No. 5, Plate VI, appears to be an adze. In all the cleavers the working edge has been produced by the removal of flakes struck laterally, and also vertically from the edge. The Early Stone Age technique was not employed, or at least I have not come across it. Mr. Clark remarks that these—

> "tranchet axes are quite distinct from those found with Early Stone Age Cultures but approximate more to those associated with the Rhodesian Fauresmith or Bembesi material (I do not refer of course to the Bembesi material alone but to the whole culture)."

Hammer Stones: These appear to be rectangular chunks of dolerite showing much battering at one or both ends. Sometimes a chisel edge has been formed.

Anvil Stones: In his account of the Bembesi industry Mr. Neville Jones describes an anvil stone, and I have found what appear to be similar objects.

Picks: Implements of this type are not quite so common as the hand-axes. They may be roughly divided into three groups. (a) Chisel ended, (b) Gouge ended, (c) pointed.

(a) No. 6, Plate VI. is of this group. A tool not illustrated is 7½ inches in length and its working end is sharpened from both sides like a cold chisel.

(b) Nos. 1 and 3, Plate IV. No. 1 is a double ended tool. The apex has been formed into a gouge like nose, the under surface being a long flake scar B. The flake was struck at the apex. The opposite end of the tool is distinctly rostroid in form and C is a flat surface, probably a flake surface, which forms the lower face of the beak. There is something of the burin and of the rostrocarinate in this implement, and I place it among the picks because its general form resembles a pick more than anything else. No. 3 has the trimmed gouge-like nose of the last described, and also the burin-like flake scar, but is otherwise of the usual pick form. Trimming on the body of the tool is confined to resolved flaking used to blunt the edges. The cross-section is roughly triangular.

· (c) The pointed forms are triangular in cross-section; the base of the triangle forms the flat, often trimmed, lower face. The upper face is keeled, and trimming is usually confined to the point. No. 2, Plate IV, is an example. Other specimens are thinner in proportion to their length. No. 1, Plate II, tends towards the hand-axe. One side is square and has been flaked at right angles to the two main faces. The opposite side is steeply inclined and formed into what may be a scraper edge. One end is rounded and sharp, the other is a blunt point. No. 2, Plate 1, is crude but appears to have been intended for use as the more finished tools. The end displays some battering of the point.

Though all the above implements have the appearance of picks, it is obvious that many were not used for picking. Some may have been used for digging out roots, but others the gouge forms for example, might have been used as scraping tools for the preparation of heavy skins, or as true gouges for the hollowing out of logs. Many were probably hafted, and would have formed efficient weapons. There are specimens which are halfway between the pick and the cleaver, or pick and hand-axe.

Scrapers: Both side and end scrapers occur, and also nearly circular ones. The end scrapers are usually thick heavy tools sometimes keeled. Their scraper edge is very steeply flaked. No. 4, Plate IV, is a good example. They are not as a rule flake tools. Side scrapers, on the other hand, are always made on flakes. The scraper edge does not display any very finely executed resolved flaking such as one might expect from an examination of the careful secondary trimming which occurs on the hand-axes and cleavers. Nosed scrapers exist. The nose is well made, and formed by notches on either side. These are the results of a couple of blows, further secondary flaking rounded the nose.

Discs: There are two disc-like artifacts. One is a perfect tool nearly circular, and worked all round the edges, and over both faces, except at the immediate butt. Dimensions: diameter 5 ins., thickness 1⅞ ins. The other appears to be half of a similar tool. Dimensions: diameter 6 ins., thickness 1⅞ ins. The edges of both are sharp and slightly sinuous.

Burins: No. 1, Plate V, has the appearance of a beaked burin of very large size. The end opposite to the beak is reminiscent of the angle burin. Here again, it seems to me, in a survival of the rostrocarinate form combined with a burin-like technique.

In addition to the above are numerous artifacts of the spall type which in some cases may have been intended for tools, but I have none which are certain.

Other types: No. 5, Plate I, is one of two nearly identical tools. The small tooth in both cases has been formed by the removal of two flakes struck from below in an upward direction. The tooth has been slightly retouched. The under face of both tools is flat. Nos. 5 and 4, Plate V, are examples of small flakes showing their unsymmetrical appearance.

Polished tool: Plate VII, No. 1. The polished surface is indicated by the unshaded area. The fine lines are striae. Reverse face not polished. Triangular in outline, and wedge-shaped in longitudinal cross-section. The polishing was done over the original weathering.

RHODESIAN STILL BAY INDUSTRY OR UPPER BAMBATA.

These implements occur among gravel where the dolerite artifacts begin to thin out. They are few in number, but nearly always perfect tools. Practically no waste flakes have been found. The material is quartz and ironstone. There is no patination, but most specimens have a slight gloss. Fine resolved and pressure flaking was used in the manufacture of these implements. The cores are of very neat workmanship, and in several cases have been retrimmed, after having been struck, to the form of miniature ovates. Nos. 3 to 10, Plate II, are typical tools. Nos. 3 and 4 are cores. No. 5 appears to be a form of tanged point, and No. 6 is a typical bifaced point. No. 8 is perhaps a fabricator. Nos. 7, 9, 10, are scrapers. The cores which have been worked over after having been struck are of the disc type such as No. 4 and may be intended for points. It is possible the material available was unsuitable for the production of flakes of any size. No. 4 has not of course been thus treated.

DISCUSSION.

A certain proportion of artifacts appear to have been used at some period subsequent to that of their original manufacture. These artifacts are usually flakes or blades showing flaking round the edges, which has resulted in the removal of some of the patina and weathering. This fact was noted by Mr. Desmond Clark who very kindly examined some of this material. I have been careful to keep a look out for these apparently re-used implements, and I have collected a number. There seems no doubt that the majority have been used by some later inhabitants of the site. Some specimens which show perfectly fresh flaking may be the result of cattle tramping, many such occur near new paths.

The Rhodesian Still Bay industry may explain the later occupation, though there is no actual proof that it is more modern than the main industry. On the other hand the tool with a polished surface (No. 1, Plate VII) suggests Later Stone Age activities.

In connection with the above it may be of some significance that a certain number of tools of the pick type, and pseudo hand-axe type, have been found in the rock-shelters in association with Wilton and possibly with the top of the Upper Bambata or Still Bay. In addition there is a small tranchet axe with a ground edge which was found on the surface near one of the shelters just mentioned. This tool very much resembles some of the cruder hand-axes from the industry under discussion, especially as it has one side trimmed to a sharp edge, while the opposite side is unworked, and the butt is square.

These finds, plus the tool with a polished surface and the re-utilized flakes, suggest either that some of the hand-axes and picks are of more modern manufacture than the rest, or that the hand-axes and picks were sometimes carried away by Late Stone Age people, and adapted to their requirements. As I have already mentioned, weathering and patina are unsafe guides at this site, and it would be impossible to pick out implements of later date by this means, assuming they exist.

Regarding the main industry, the absence of any stratigraphy is unfortunate, as there can be no definite clue to the true position of the assemblage in the Rhodesian Stone Age without it.

The only other occurrences of this industry I know of are also on the surface, but tools may now and then be seen near small outcrops of dolerite on the banks of the Sabi river. These are unrolled but weathered, and their position indicates that there can have been no great rise in the river level since their manufacture. Rolled tools of Early Stone Age type occur in a coarse gravel exposed in places below the alluvium in the bed of the Sabi. I have been unable to locate any river terrace in this area except the one first mentioned.

To return to the site under discussion. The cores appear to me to be very undeveloped, but this does not necessarily mean they are very early. They may possibly be degenerate survivals. The prepared core technique has of course been proved to exist in the Early Stone Age. Van Riet Lowe illustrates some in " The Geology and Archaeology of the Vaal River Basin." Judging by the photographs those cores are more developed than mine. The facetted striking platforms seem more complex, and the resulting flakes much more symmetrical. The crude form of these Sabi cores may not point to an early date for their manufacture, and the tools which are associated with them seem to prove this. They give the impression of being survivals of older forms. The hand-axe, the cleaver, and even rostroid forms are present, but the technique has undergone a considerable modification. The picks too require explaining.

Mr. Clark considers the industry has "Bembesi affinities" and places it somewhere in the Middle Stone Age. That is as far as it is possible to go without further evidence. The only certain fact seems to be that an Early Stone Age date is most unlikely.

ACKNOWLEDGMENTS.

I should like to thank Mr. Desmond Clark for examining some of the material from the above site, and I should also like to thank Mr. Neville Jones for advice on several occasions.

PLATE I.

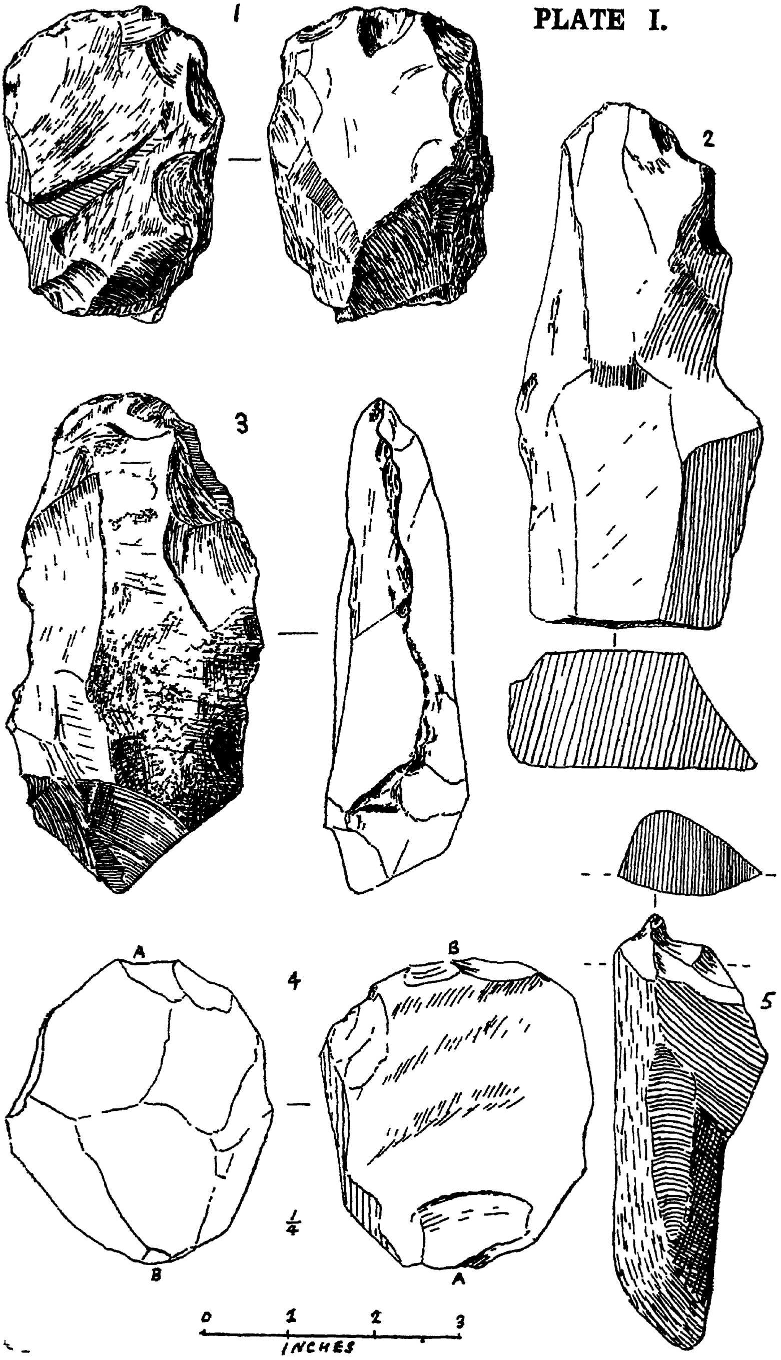


PLATE II.

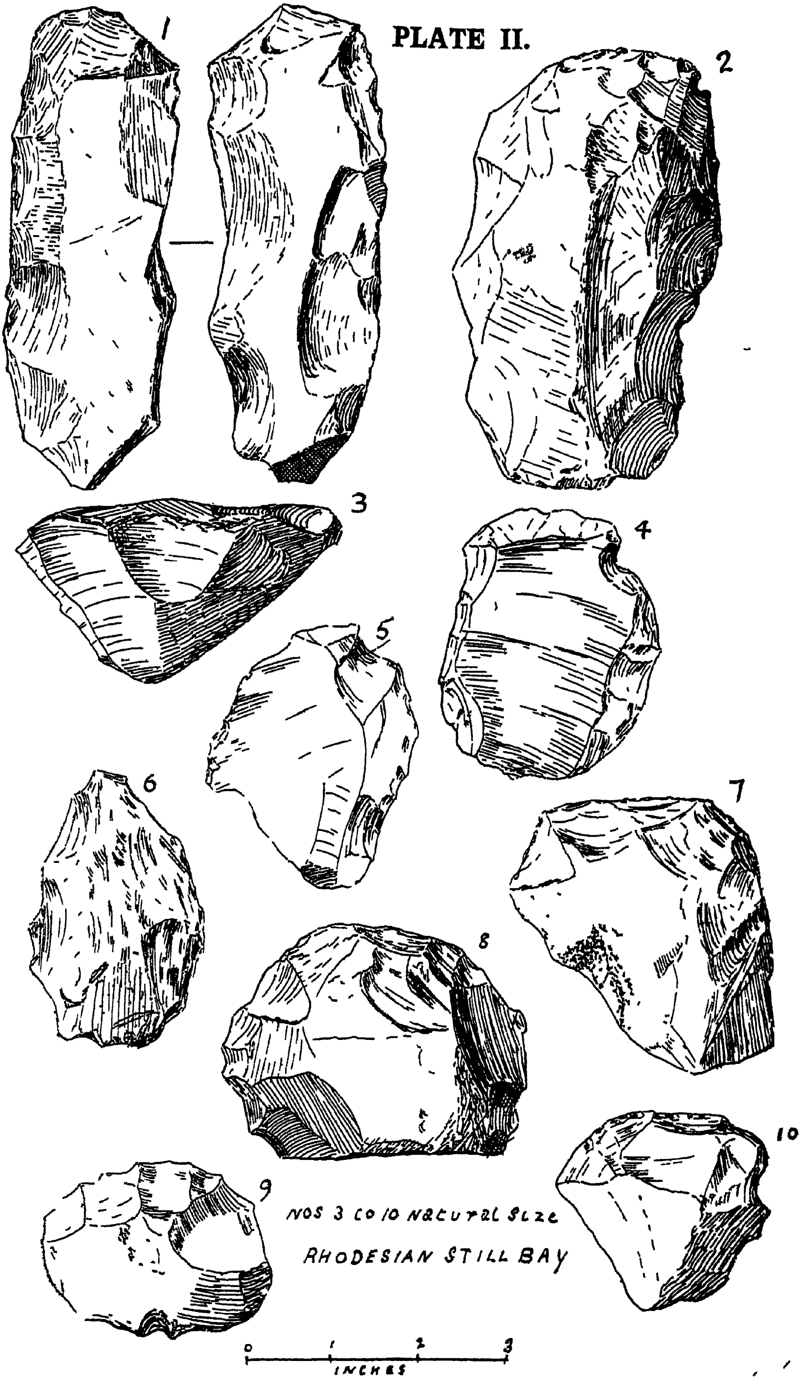

1
2
3
4
5
6
7
8
9
10
NOS 3 to 10 Natural Size
RHODESIAN STILL BAY
0
1
2
3
INCHES

PLATE III.

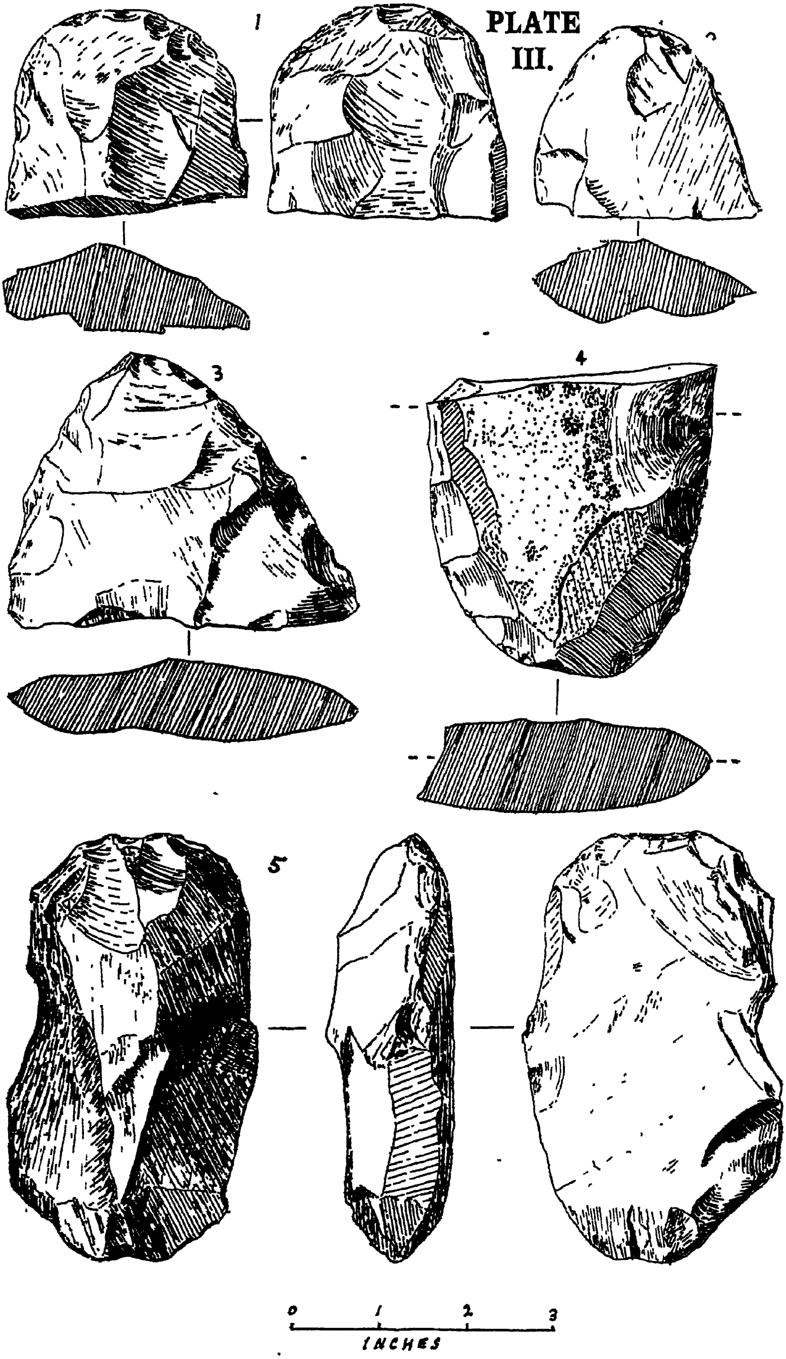
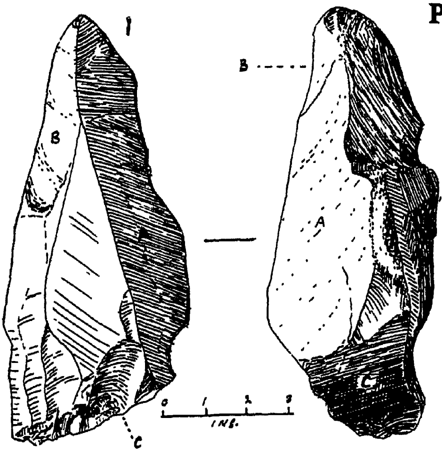
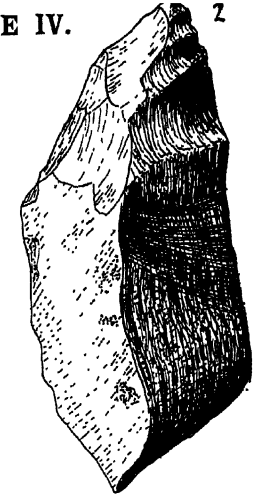
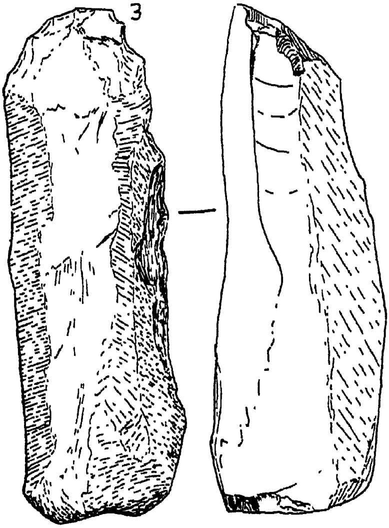
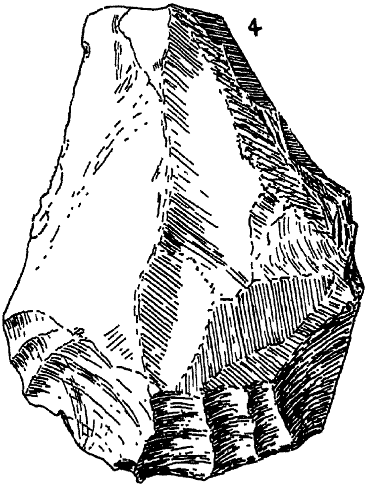


PLATE IV.









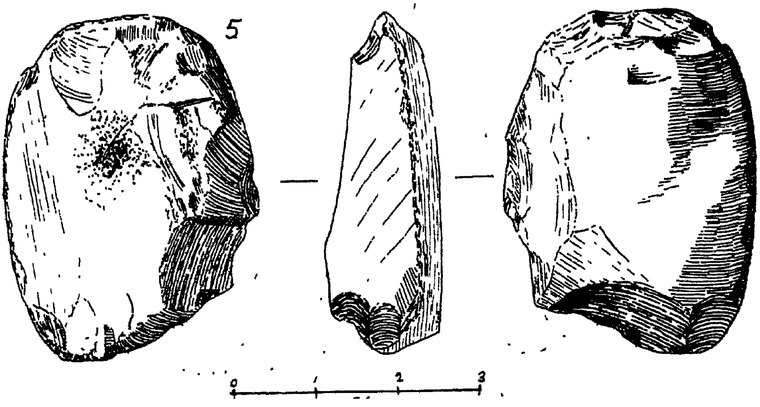
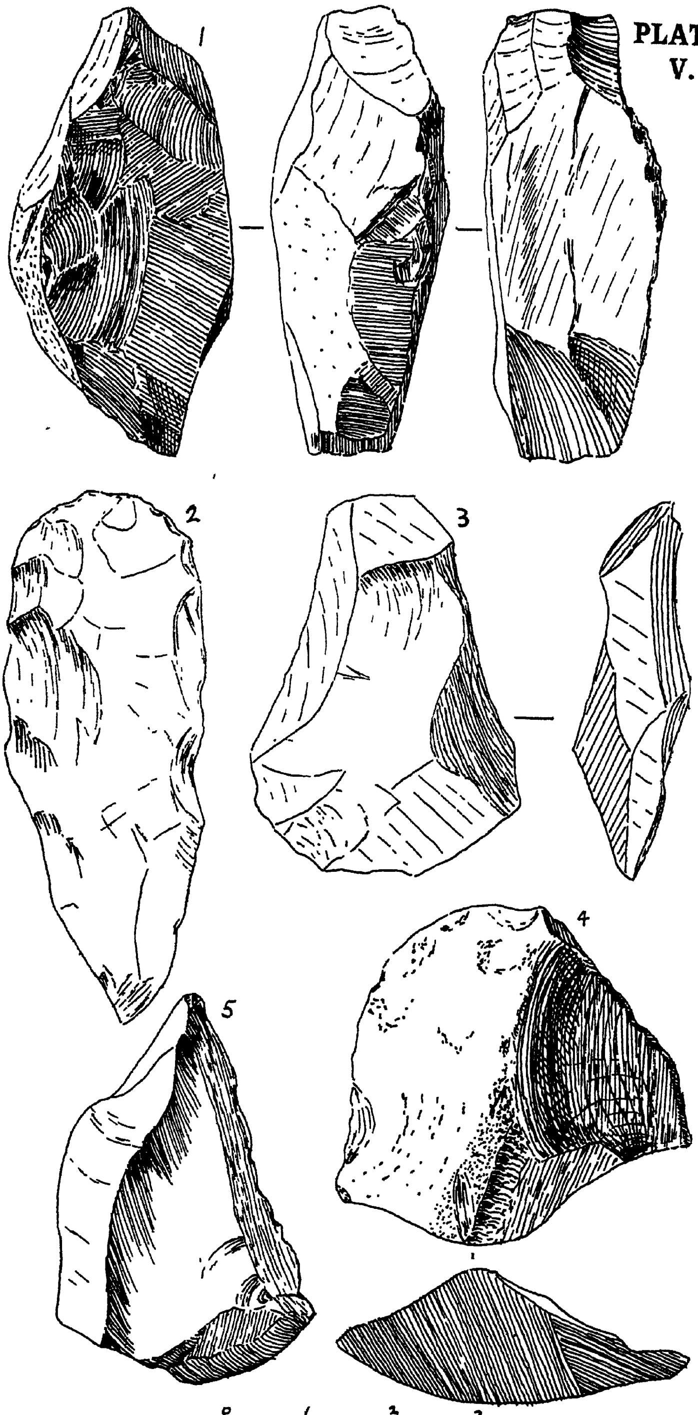


PLATE V.



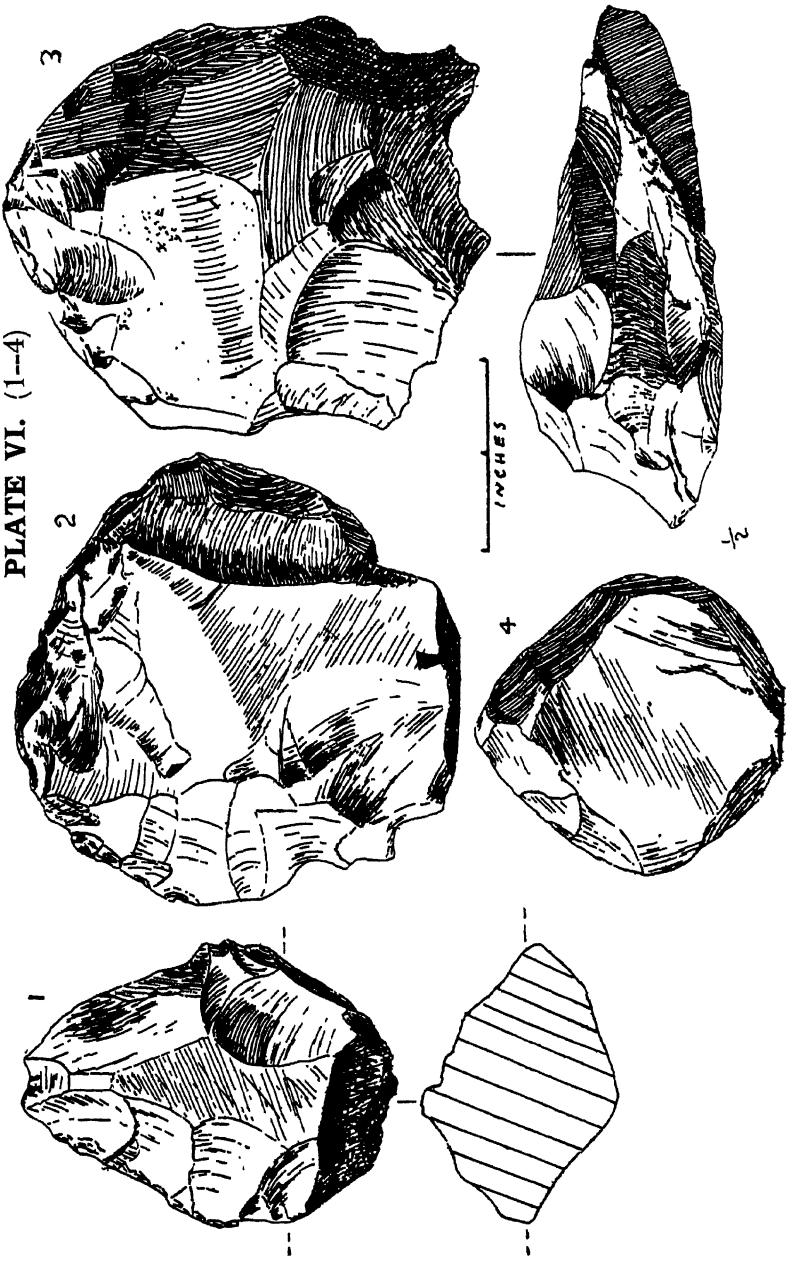
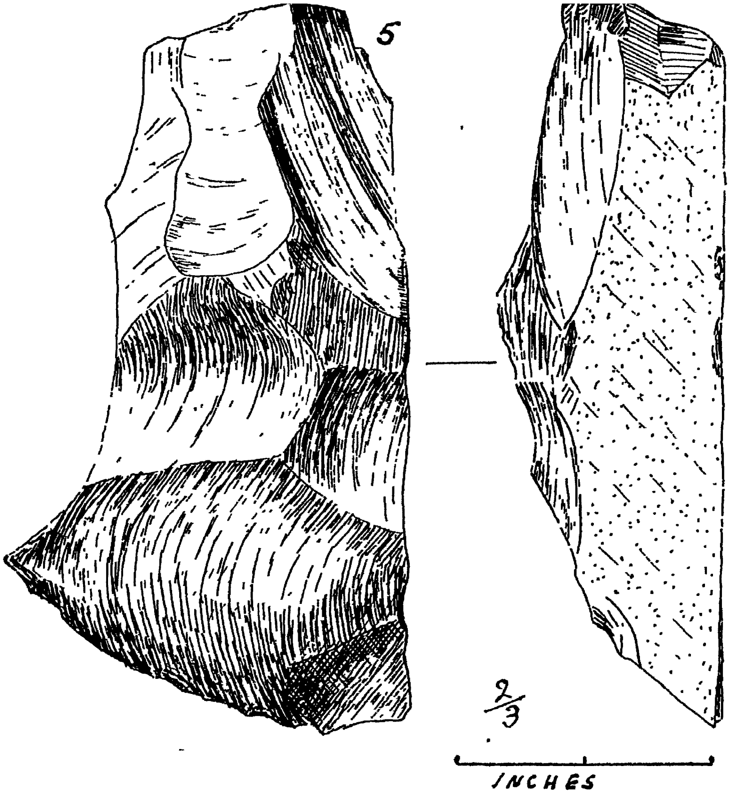


PLATE VI. (1–4)

PLATE VI. (5–6)

5



6

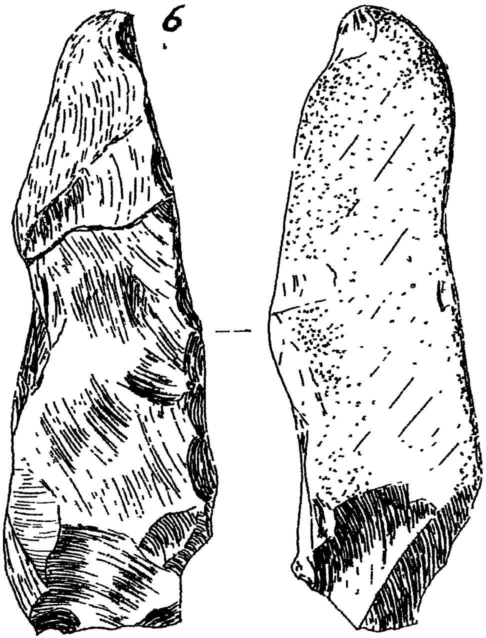


PLATE VII. (1, 2)

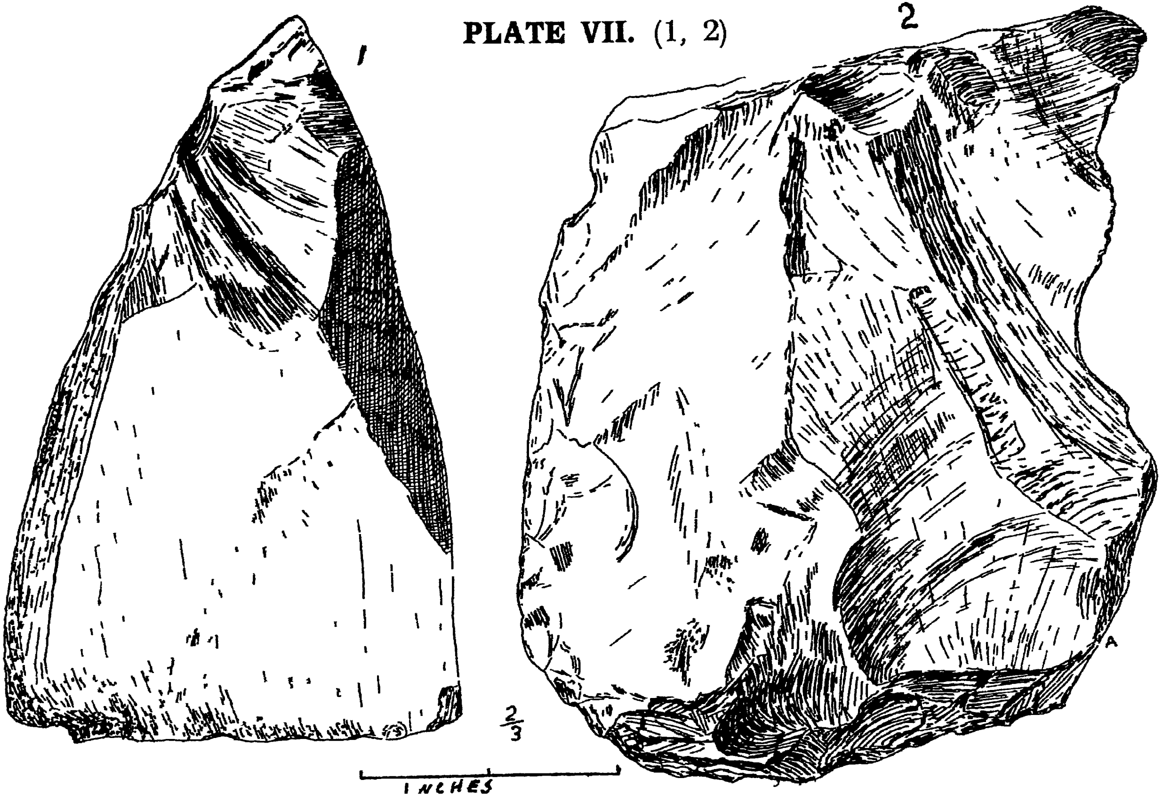
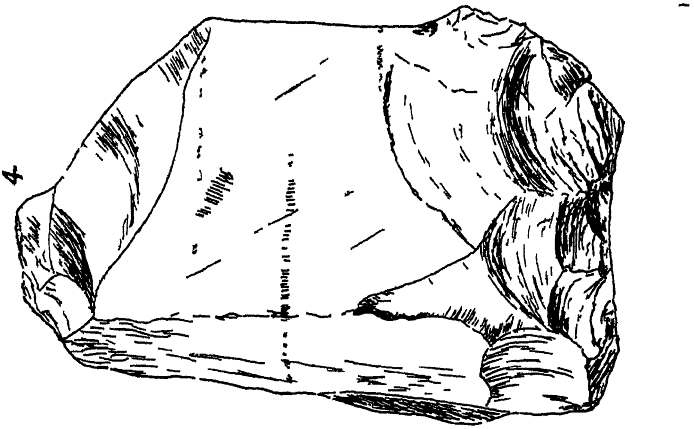
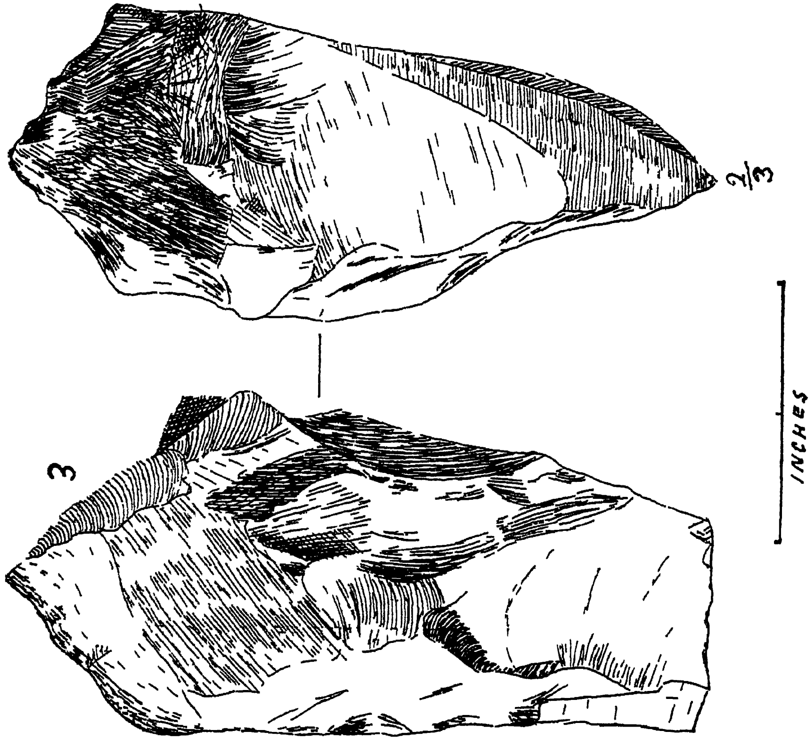


PLATE VII. (3, 4)

4



3



SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXVII, pp.* 345-349.
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ROCK PAINTINGS IN SOUTHERN RHODESIA

BY

THE HON. L. CRIPPS,
Umtali, Southern Rhodesia.

Read 1st July, 1940.

Some years ago when taking up the study and copying of the Rock Paintings, in this country, I did not realize how big an undertaking that would become. Now I discover that their numbers run, in all probability, into thousands, as they are found throughout the Southern, Midland and Eastern districts, wherever the granite formation occurs, from Bulawayo in the West to Umtali on the Eastern border.

As the work proceeded the figures that at first appeared as a mere jumble, thrown hap-hazard upon the rock faces, acquired an individuality and sense of design, which the Artist had been at pains to express, thus increasing the interest of the pictures and giving fresh hope of finding much that was worth while.

I have long held the opinion that primitive people are purposeful in a serious way, and that their undertakings are carried out in that spirit and not merely as a way of passing the time, and I could not, therefore, picture the Artists painting on the Rocks for fun, sport or even to satisfy an aesthetic longing, but rather because it would serve some serious purpose, especially when occupying themselves in such an uncommon work as painting.

In South Africa we know many tribes of relatively advanced peoples who only paint as children would, so that when we come upon paintings executed well enough to convey a feeling of satisfaction, the people who did them are well worthy of study.

From Northern Africa to the Cape of Good Hope, at intervals are found paintings of much the same character, culturally connected with similar work in Europe, and all possibly done by people of one race, who in their migrations carried along their art. It would seem that such a survival would not have occurred unless it had served a vital need, especially when taking into account the effects of new environments in the vast distances covered.

When the driving force behind the Artists' efforts, which made for survival was considered, it became apparent that this must have been in the nature of religion, the practice of which they, in common with all African peoples, carried into their everyday lives. Powers of good and evil had to be dealt with and propitiated.

With these ideas in view the interpretation of the pictures was simplified. Groups occurring on vast rock faces covered with paintings could be isolated and studied separately, the rest of the figures being left for further consideration in order to find out whether they could be connected with the groups or not. In most sites the paintings, being few in number and covering small spaces could readily be dealt with and recognized as serving a single purpose only.

The majority of paintings are in granite country. Rock shelters were chosen where available, but many paintings are to be found on exposed rock surfaces. There appears to be no tendency to choose sites facing to any particular point of the compass, as in the same shelter they often face in several directions and the shelters themselves face in all directions. Sites are often concealed by vegetation, rendering approach painful and difficult. Some sites show evidence of recent use by later inhabitants as refuges in times of stress; stone walls often occur at or near them, built for kraal and defence purposes.

Of special interest in a great number of shelters is the presence of graves, often under the painted rock face. The space under the rock, after the body had been put in place, was built up with well shaped granite blocks. Where these stones have been disturbed the skeleton may be seen inside the original grave or scattered on the shelter floor. In one case the bones in a grave had been burnt. Some shelters have been used by the present day natives as burial places, and are recognized by them as belonging to their own people.

There is no absolute proof that the graves and the paintings had any connection with each other, neither is there proof that the people in the graves were Bushmen. It seems, however, highly probable that they are connected, as the paintings themselves of dead men and women show. The modern natives have no skill to-day in painting, nor have they any notion as to the authorship of the paintings.

We turn now to the paintings themselves and give some details as to the colours used, their superposition and the methods of grouping. I have visited well over 600 rock shelters. From 580 sites I have sketched or traced 7,066 figures. These have been reproduced in colour in albums.

The greatest number of such figures in one site is 250 and the smallest number 1. The numbers done in Claret in all its shades are 3,090, while those in Red of all shades are 3,035, in Yellow 481, Brown 247, Black 92, White 56, Pink 64, Blue 1. The Superpositions are as under:—

Claret on yellow (15), Brown (8), Red (13), Black & White (2)=38 times.

Red on Brown (2), Claret (11), Yellow (7), Black (3), White (1)=24 times.

Yellow on Claret (9), White (1), Red (5)=15 times.

Brown on Claret (9), White (1)=10 times.

Black on Claret (4).

White on Claret (1).

It would seem, therefore, if superpositions are to be taken as representing age, the order would be: (1) Claret (the most recent), (2) Red, (3) Yellow, (4) Brown, (5) Black, and (6) White, being the oldest.

In this connection I may remark that Claret in patches or stripes appears on same figures in Yellow (1), Brown (2), Red (1), while dark and light Claret appears on same figures as Pink.

Red appears on same figures as Claret (25) and on Yellow (2), White (7) times.

Yellow on same figures as Claret (3), Brown on same figures as White (2) times.

Black as stripes on White (2), White with Yellowish patches (3) times.

Graves are found in or in close proximity to paintings in 93 sites.

Dead people, nearly all males, are found in 140 groups. Figures, falling as if wounded, charged by wild animals hanging head downwards, falling off rocks, or with arms and legs chopped off, may be added to these.

In 35 groups there are paintings of weapons, unattached, and in these groups there are men and women dancing or in attitudes of grief. In one of the above groups there are as many as 20 dead men.

I have not opened any graves, as I know natives would object, and past experiences have shown the necessity for caution. All graves are now protected by Law. The human figures are of men and women, and in very few instances are children or babies portrayed. The figures are generally well drawn and among them are truly heroic figures, but the portrayal of the eye does not appear ever to have been attempted. All the men's figures are nude, except where, occasionally, small back and front aprons are added. Eighty-three varieties of men's head-dress have been noted, the men's fashions out-doing those of the women by a mere 30, while 29 varieties of masks and head-dresses are in evidence.

The figures of women are often in the nude, some showing pronounced Steatopygy, many are dressed from the waist down in short aprons or skirts, a few wear long gowns, while rare examples wear what appear to be vests and shorts reaching to the knee. A few cloaks are also to be seen. Men and women are shewn as on the move and vigour and grace are indicated. Grief is well represented by drooping figure, bowed head or hands raised to level of the head. Excess of emotion is shown in quick movement and whirling draperies. The raiding warrior, the slave chaser, the daring but cool-headed hunter, the stately Chief accepting and the humble vassal offering his gifts, the graceful attitudes of dancing women are all well portrayed, and not mistakeable for anything but what the artist obviously intended. The contacts with foreign peoples, the arrival of the Zulus and Shangaans, the riding-ox and the ringed warrior, the robed visitor from Eastern parts, the pig-tailed executioner with his sword, the new weapons of the boomerang and muzzle-loading gun, the arrival of horse and donkey, cattle, sheep and goat and canoe have all been noted. One of the most extraordinary productions is the labyrinth in a figure 4 ft. x 4 ft., out of which one feels it would be difficult to find an un-blocked exit, with a tall robed figure underneath. There are no attempts at obscenity.

The Wild Animals are Elephant, Rhinoceros, Hippopotamus, Giraffe, Zebra, Eland, Kudu, Roan and Sable Antelopes, Waterbuck, Tsessebe, Reedbuck, Impala, Bushbuck, Duiker, Lion, Leopard, Cheetah, Jackal, Baboon, Wild dog, Porcupine, Ant-bear, Cane-rat, Red-hare, Springbok, Dassie, Ostrich, Crane, Bateleur Eagle, Goose, lesser Locust-bird, Locusts, Fish, Eel, Snakes (some with Duiker heads), Crocodile. There are also Trees, Rocks and Plants.

In conclusion I consider it likely that all paintings are, directly or indirectly, connected with the Funerary Rites, either of the people who did them or for whom they were done. The cause of death is often shewn, as are the weapons and possessions of the dead man, the food to be eaten, the Totems and the game animals. I am aware that all the above do not appear invariably, much flaking having taken place; but their environments, the dead men, the attitudes of the dancers, the weapons, the animals depicted, the graves, and last but not least the known attitude of primitive man towards, and the respect due to, his ancestors suggest and justify my conclusions.

SUMMARY.

It is now becoming evident that Rock Paintings in Southern Rhodesia are far more numerous than was generally thought likely in past years.

A serious definite purpose is apparent in their composition, and, owing to the presence of dead people together with their family animals or Totems, also with groups of mourners and graves, close to or under the painted rocks, it would appear that the paintings were connected with funeral rites and ceremonies, the animals represented being either the cause of death or linked up in some way with the ownership of the site.

There are no signs of orientation in the sites chosen or in the paintings in them, these sites being generally in granite country.

The present day people are considered to be probable descendants of the painters, as their ways of life, their method of singing and their weapons are similar to those of the Rock Painters, although they do not paint nowadays nor have they any traditions as to authorship.

It is shown that Claret, Red, Yellow, Brown, Black, and White were the colours used in the figures numerically in the order given. Super-positions are in the same order, as regards numbers.

The conclusion arrived at is that all paintings are probably connected with the Funerary rites either of the painters' people or of others for whom they were done.

South African Journal of Science, *Vol. XXXVII, pp.* 350-360.
February, 1941.

MANYIKA POTTERY,

BY

C. Martin,
M'Kondwe, Penhalonga, S. Rhodesia.

Read 2 July, 1940.

The art of making pottery is gradually dying out in Manicaland as elsewhere in Africa. Although the potter's daughters learn the craft it is doubtful whether they will ever practice it, for the old potters say that there is little demand to-day for their wares.

Among the Manyika as in other Bantu tribes the making of pottery is a woman's craft, and it is hereditary, certain families specialising in it and retailing their wares to the clan. The pottery is made of a local greyish-yellow clay which turns red when fired, and it is generally undecorated, even that of the chief's wife being severely plain. It is said that many years ago the shoulder of the pot might be ornamented with a line or with a band of some design, but it is evident from the potsherds found in old habitation sites—even in one known to have been occupied by a chief—that the practice was not general. Occasionally mica schist was pounded up and mixed with the clay, giving a speckled appearance. Graphite is sometimes used as a burnish, but incised decoration is very rare.

The ordinary household pots number six, and are illustrated on Plate I, A. The two big pots (left to right) are called "*Gate*" and "*Musudzi.*" *Gate* is used for brewing beer, *musudzi* for prepared beer, and also to store grain, with a flat stone or large potsherd as a lid. The smaller pot of the same form in the middle of the group is also "*Musudzi,*" and is used for carrying and storing water, and occasionally for beer. The open bowl on the left, "*Mantekhari,*" is for cooking porridge, and the small, narrow-mouthed vessel is "*Chipfuko*" for cooking vegetables. The little dish is "*Mbiya,*" used for serving relish, "*muriwo.*"

There are slight variations in form and size, but these are the typical forms in general use. The beer pots may be very much larger than those illustrated, and there is a big beer pot with two mouths, (Plate I, B) called "*Mbidziro,*" used only by chiefs and headmen on important occasions, such as the "*Maganza*" (seeding time feast). The two mouths are said to show the hospitality of the host, for two people can help themselves from it at the same time, using a gourd ladle. Another form, now obsolete, is a long-necked flask called "*kaka.*" The wife brought this to her husband so that he might taste the beer when it was ready. Animal shaped pots are not made by the Manyika.

Kunyadza Ndodini, widow of Chief Chakaoneni Muponda, is a noted potter. In July 1939 she kindly agreed to come to my house and make some pots there, so that I could see the whole process. My cook acted as interpreter throughout the proceedings.

We went one morning to the place where they get the clay, "*Chidziwa,*" which is on our own farm. It is on a slope above a little stream and about on a level with the springhead. The soil is yellow to blue-grey, and is full of small hard white granules. Loose earth lay over an area of some forty square feet, and the old woman and her daughter-in-law, Mwaraseni (with baby on back), selected a corner and took out the loose top earth with an old hoe (Plate I, C). When the untouched clay, "*Ivu,*" was reached, about three feet from the surface, they started to fill the two baskets they had brought with them. The clay was moist and heavy and showed blue-grey where the hoe cut into it. The young woman dug, while the old one examined each lump, breaking it and removing any stray grass, root or extra coarse granule before putting it in the basket. Even the baby helped.

When the baskets were full, the excavation was carefully filled in again with loose clods of earth, presumably to conserve the moisture. The young woman twisted rings of grass, and on these the heavy baskets were balanced on their heads for the walk back.

A large flat slab of granite, "*Guyo,*" had been found, and this was put on a level piece of ground, which was first carefully swept. Two poles, "*Motu,*" some six feet long and three inches in diameter, were selected, and the pounding of the clay began (Plate I, D). Nothing was added to the clay, and, apart from picking out any noticeably coarse granules, nothing was taken from it. The pole was thrust down into the mass of clay, given a short twist and then drawn up again. Water was sprinkled on the clay at the commencement, and the pounding lasted about half an hour, when the clay had become a heavy wet dull yellow paste. When the pole does not come readily out of the twist, the paste is of the right consistency.

Both women made a large beer pot of the *musudzi* type The old woman used her own basket of withies, and the young one an old enamel dish without a bottom, in which to lay the foundation of the pot.

Lumps of clay were formed into a rough ring in the bottom of the basket or dish. Then, working from the inside, the sides of the first two fingers of the right hand scooped the clay upwards and sideways, any superfluous clay being pressed back on to the top of the pot wall by the thumb. The left hand supported the outside and kept the pot a good hand's breadth away from the side of the dish or basket (Plate I, E). Lumps of clay, twice the thickness and length of the thumb, were now added along the top. The old woman merely manipulated the clay before using it, but the young one rolled it between her hands. The rolls or lumps of clay were pressed down by a quick slanting stroke of the thumb. and a complete circle added before it was worked into the wall. The thickness of the wall was about one centimetre, and the process of inside scraping and supporting from the outside was continued until the pot was semi-spherical and had attained its maximum diameter (Plate II A). The inside was then smoothed with the curved edge of a piece of calabash "*Nhemba*," dipped in water, and the outside was similarly treated, but with a flat strip of bamboo, "*Swipariro che hari*," the flat side being used in a downward motion. The left hand always supports the pot wall during this operation. The effect is miraculous, converting a rough finger-marked surface into a smooth even face (Plate II, B).

The process of adding to the pot was then continued, but this time the pot wall was sloped inwards (Plate II, B, C). The left hand supported the inside of the wall, and the tips of three fingers smeared the clay sideways and upwards in what was almost a spiral effect (Plate II, C, D). The shape of the pot at this stage was elongated, and the reason was later apparent, for the weight of the clay caused the pot to settle down on itself, as it were, and the lower part then conforms to the shape of the basket or dish, and the upper part takes to itself a comfortable curve. When the required height was reached, the smoothing process was repeated, some pressure being exerted from the inside to accentuate the curve of the shoulder, leaving a tapered neck. This was made slightly concave by judicious external use of the *nhemba* (Plate II, B).

The building of the pot was accomplished with speed. but the shaping and finishing of the lip, "*muromo,*" was a lengthy process, taking as long as an hour. In these days and in these parts the lip is generally tapered and slightly everted, but the old potsherds more often show a rounded lip, or, less frequently, may be squared. The neck termination was left very thin, but with wet fingers a little clay in very thin layers was added from the inside and smoothed swiftly and delicately with the *nhemba*. A little more was added, a little taken off, and more smoothing. There would be a critical survey, and a word of advice would pass from one to another until the correct taper was obtained. The slight eversion of the lip was effected by a deft stroke of the edge of the bamboo just below the lip edge externally. As a final touch the old woman took a small piece of dripping wet skin, and with thumb inside and finger outside the lip, walked solemnly round the pot (Plate II, F). She can barely have touched it, for the form remained the same, but the finish was perfect. She finished the daughter-in-law's pot in the same way, and it was noticeable that she advised her fairly constantly, and was obeyed without argument.

I wished to make a *mantekhari* myself, and this was started from a small lump which formed the bottom and the beginning of the wall. The old woman could not bear to see my clumsy efforts, which were greeted by both with derisive laughter, and she constantly took the pot from me to correct my mistakes. I managed, however, to do enough to appreciate the skill of those nimble old fingers, both in keeping the wall an even thickness, and in preserving the curve, which seemed to become wilfully distorted. The handling of the simple but effective smoothers also required a nicety of judgment and touch which was not learnt in a day.

It was damp and misty, and the pots were put under the shelter of the hut eaves to dry.

The next day a little more smoothing was done, and the old woman decorated her pot (Plate III, A). I enquired why she did this as it was not the custom, and it appeared that, although a Manyika, she came from Portuguese East Africa south of Macequece, and had been taught by her grandmother to decorate the pots. Possibly the grandmother came from another tribe, or the decoration may have been imitated from the Shangaan pots. She said that she did it for play, and her efforts are crude and designs original, following no set scheme.

The decoration was made with a thin pointed stick which she licked constantly. Two parallel horizontal lines, four inches apart, were incised on the shoulder. These were filled in with oblique or curved lines, two or three inches apart, and the alternate spaces thus formed were filled in with dots. Round the shoulder of the young woman's pot she merely drew a single horizontal line.

The small *mantekhari*, which had been finished for me, was fairly dry, and was now turned upside down. In the dish which I had used she now made another small pot, *chipfuko*. This was also made complete with bottom, and had an unusual lip. After making the usual tapered lip, she added externally, about an inch below the rim, a raised rib of clay which was tapered out to form an extension, by a concave line, of the true rim (Plate III, C, D). All this was accomplished with great care and patience, and the effect was interesting. I think it possible that she was showing off, however, for I have never seen such a finish to any local pot.

The next day she added three legs and a lid to the *chipfuko*, which I thought rather spoilt its perfection. The big pots were sufficiently dry to turn upside down on to a cloth, and the bottoms were now added. Clay was applied to the rough edges of the base, shaping and scraping with the right hand on the outer side, while the left supported the inside and helped to form the curve. When only a small space was left unfilled, the fingers of the left hand were used, till at last a little hole about an inch and a half in diameter was left, and this was merely plugged with a piece of clay the right thickness, and the outside smoothed with the reed (Plate III, B).

Again the pots were left to dry, this time bottom upwards. Next day they were sufficiently dry to be placed the right way up, very gingerly, in a little hollow lined with a cloth. The inside was well scraped with the *nhemba*, which required the use of some force as the clay was stiff and rough. The superfluous clay which was scraped off was used to fill in any hollows and irregularities inside the pot, and when finished, the bottom, both inside and out, looked just as good as the rest.

The old woman brought her little grand-daughter that day, and they applied some graphite to the lips of the pots (Plate III, C, D). This was done by licking the lump of graphite and rubbing it on. More rubbing done with the fingers and a small quartz pebble used to give the final burnish. Some was also put on the big pot in the alternate blank sections of the decoration. The pot lid was covered with it. A much larger quartz pebble was used to smooth the now fairly hard surface of the pots. All this was done to "*gadzira*"—prepare—the pots for burning. Colour decoration of any sort is called "*Chidziro.*"

They said that the graphite was obtained from some way away, either Inyanga or Mutewe, and was brought by pedlars. Another pigment of which the old woman knew is a soft red earthy substance—not ochre. She had a little, which she said came from Macequece, and brought it next day to add to the beauty of her big pot. It was moistened on a stone with a little water and applied to the pattern with a "brush" made from a dry twig (Plate III, E). Some more polishing with the pebbles was done, and some small dry "*msasa*" wood brought in preparation of the morrow's burning.

The next—the seventh—day, more wood was brought. Grass should have been cut, but to save time the women asked if they might use some dry grass stacked nearby. A space about five feet square was cleared with a hoe (the baby again helping), so that the ground was made level by a little banking up of the downward side. It was not even a depression. On it the wood was arranged criss-cross, and the pots placed thereon. The big pots were right in the middle, and the smaller ones nearer the edge. The rest of the wood was carefully arranged around and over them (Plate IV, A), and the dry grass piled thickly over the whole. No fuel was put inside the pots.

The old woman next fetched a glowing stick and lighted a tuft of grass from it. This she thrust into the base of the heap on the windward side, and blew it gently until a great cloud of white smoke arose from the top (Plate IV, B). A little flame appeared and gradually the whole pile was reduced to a black mass, glowing red inside. It was carefully watched, and more grass put on when there was danger of it falling off. I suspect that freshly cut grass would have been better, as they were worried about it falling off too quickly. I discovered later that this caused the pots to become smoke-blackened.

After fifteen minutes the smaller pots, burnt to a dull red, were gently edged out of the heap with a stout stick, but were not taken right away from the fire for another five, when they were rolled gently away and left to cool with a little hot grass ash and charcoal inside. In another ten minutes the big pots were partly exposed (Plate IV, C). An anxious tap was given to each pot as it emerged, to see whether it rang true. Luckily none were cracked.

There was much consultation about the big pots. They were shifted here and there to get more even burning on the hot charcoal. They took over an hour to fire and another hour to cool off (Plate IV, D).

Plate I. A. Ordinary Manyika household pots.
B. Two-mouthed pot, also gourd ladle and drinking vessel.
C. Excavating clay from pit.
D. Pounding clay on granite slab.
E. Beginning to build the pot.

Plate II. A. Building up sides of pot.
B. and C. Building upper portion of pot; the lower part has already been smoothed.
D. Shaping mouth of pot.
E. Smoothing upper part of pot.
F. Applying finishing touches to rim.

Plate III. A. Decorating pot with incisions.
B. Finishing base of pot.
C. and D. Applying graphite and burnishing with pebble
E. Applying pigment to pattern.

Plate IV. A. Arranging pots and fuel for firing.
B. The commencement of firing.
C. Extracting pots from the fire.
D. Pots at end of firing

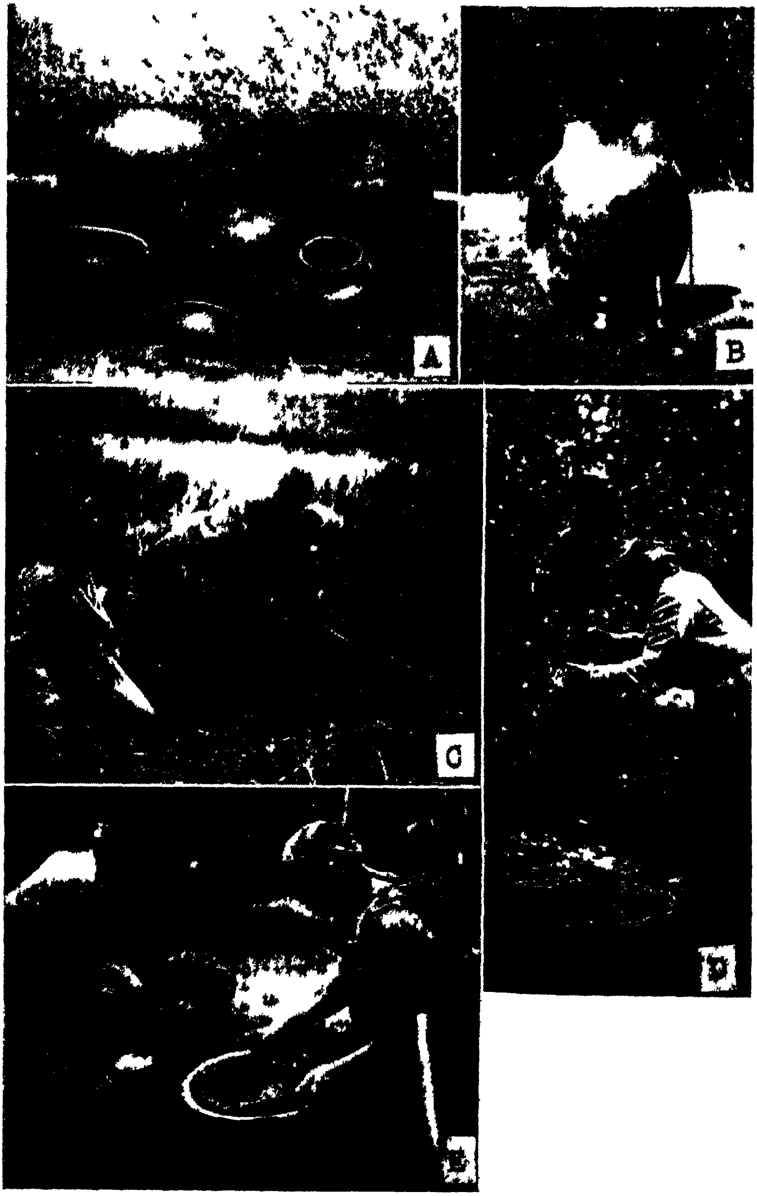

PLATE. I.

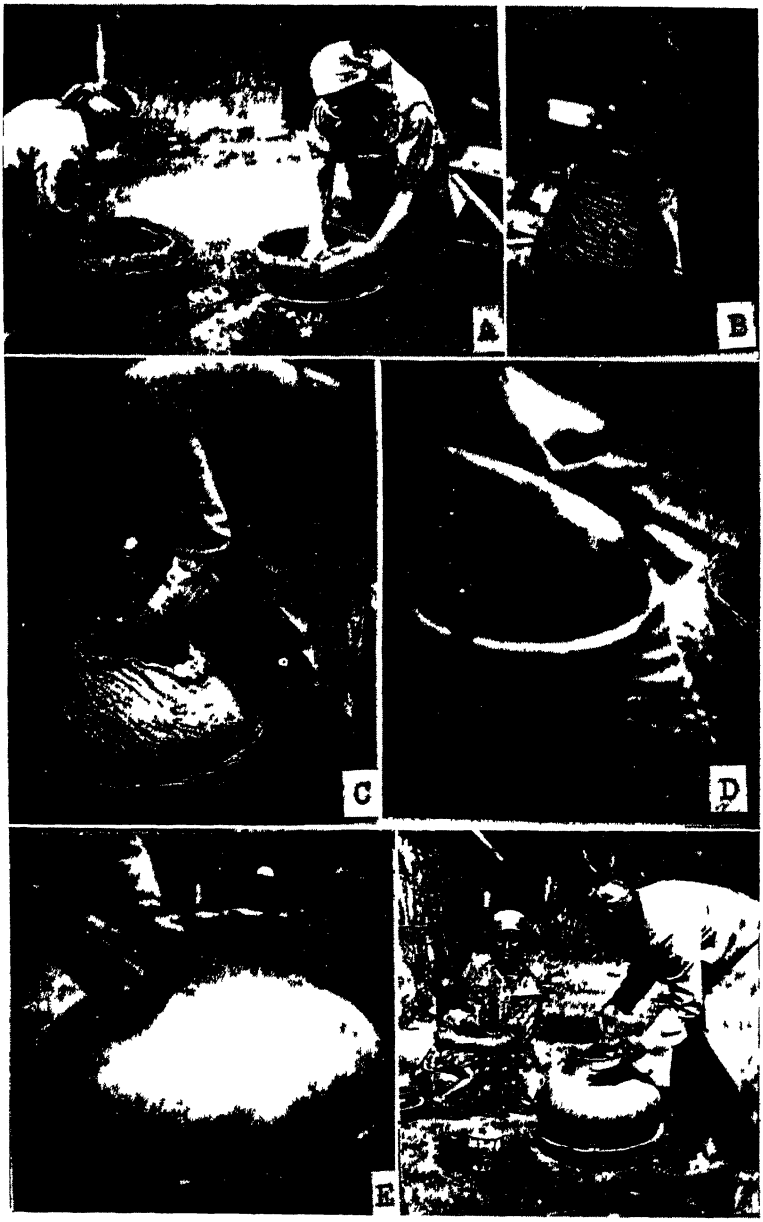

PLATE. II.

PLATE. III.

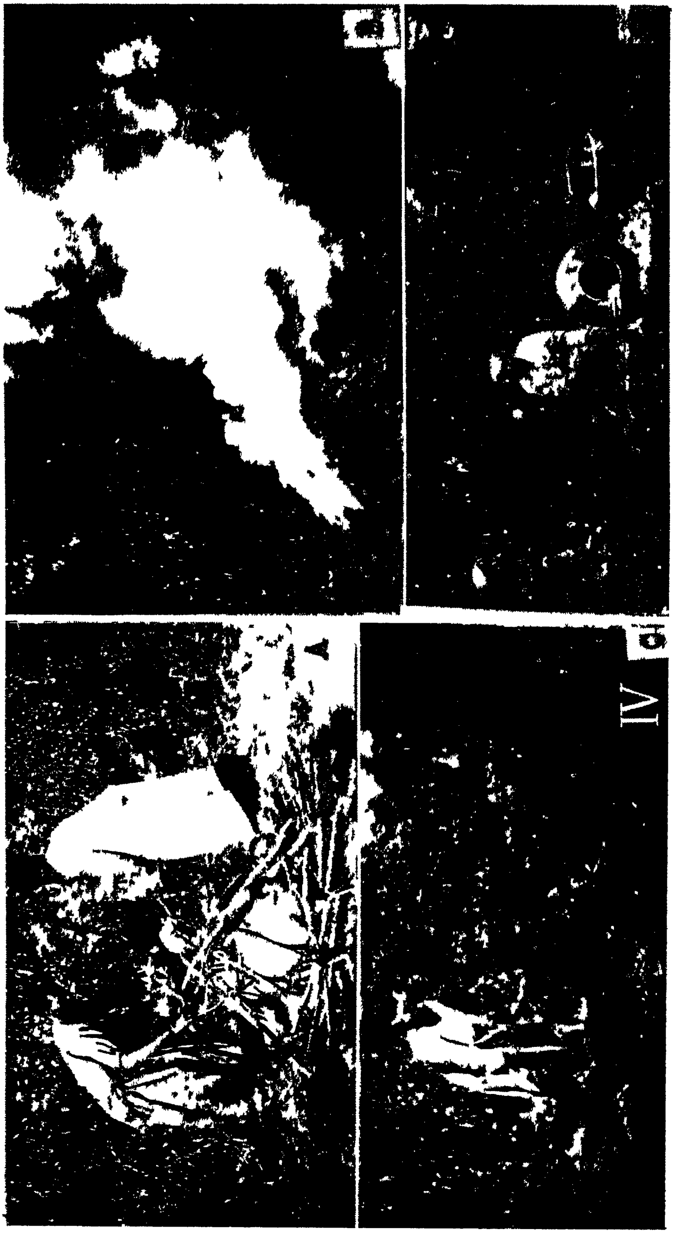

PLATE IV.

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A REPORT ON THE POTTERY FROM BAMBATA CAVE

BY

J. F. Schofield, *Durban.*

Read 1st July, 1940.

Introduction.

It was only during the last decade that the recent prehistory of Southern Rhodesia finally emerged from that twilit region of romantic speculation, in which it became involved, when the first explorers of our more striking ruins concentrated on the recovery of golden ornaments and soapstone bowls. While these objects were ascribed to a great and uncertain antiquity, the pot sherds which were everywhere associated with them, were, from their obvious affinities to modern Native wares, relegated to oblivion. It is not too much to say, that if the pottery found at Dhlo-Dhlo, Khami, Zimbabwe, and other " ancient " ruins had been preserved, not only would our knowledge of those places be vastly greater than it is, but many of the unsolved problems of the origin and history of our Native peoples would be made clear to us. As it is, the scientific study of ceramics in South Africa dates from the publication of Zimbabwe Culture, when Caton-Thompson placed us all in her debt by proposing the first classification of our wares (Ref. No. 1). Further study has shown that this classification has a very general application, and in order to recognise this, we have proposed to use the symbols R_1, R_2, R_3 etc., instead of the alphabetical denominations originally proposed (Ref. No. 2).

It will be seen therefore, that it was a piece of the greatest good fortune, that the pottery which was discovered during the original excavations at Bambata, was saved from destruction and placed in the Rhodesian Museum. After lying there for some twenty years, it was again examined by Mr. Neville Jones in the light of fresh material, which he had recently excavated from the upper stratum of the Cave, and which seemed to him to be entirely different to any purely Native pottery with which he was acquainted. It thus happened that the whole of the pottery from Bambata was submitted to the writer, and the following Report came to be made. This, although it sheds little light on the origin of the wares, at least emphasises their interest and value.

DESCRIPTION OF THE POTTERY.

(a) FABRIC, MANUFACTURE AND FIRING: All the pottery recovered from Bambata Cave had been hand made. The clay used appears to have been entirely natural, for there is no evidence that it had been tempered by the addition of any extraneous ingredients. It is impossible to determine by what method the pots were made, for there is nothing to show us whether they were raised from the lump, or made by the riband technique, or some variant thereof. The pot walls vary considerably in thickness, often in the same pot, in some of the small vessels it is no more than 3mm, but in others it is as much as from 10 to 15mm.

The great majority of the sherds examined were found to be of a black or grey colour. It is therefore probable that they were burnt on an open fire, and that no kind of kiln was used. A few of the sherds which have a buff colour, are much better burnt, but since different pieces of the same vessel show widely divergent degrees of burning, it is evident, that these buff sherds have been subjected to accidental secondary burning, such as is likely to occur on any midden.

(b) TYPES OF VESSELS: The whole of the material is so very fragmentary, that the original form of many of the vessels must remain in doubt, but the following types have been well established.

Bowls. As Nos. 3 and 12.
Shallow Bowls. As No. 6.
Pots and/or Bowls with constricted openings. As Nos. 1, 4, 8, and 9.
Beakers. As Nos. 5, 15 and 16.
Pots with Flared Necks. The smaller of these may also be Beakers, as No. 14, while the larger,
No. 11, were probably food pots.

(c) DECORATION: The pottery was decorated by the following methods:—

(1) *Surface Finish*: The surface of the pottery had been finished in three ways, (a) it was left smooth from the hand (No. 15), (b) it was burnished (No. 12), or (c) most commonly of all, it had a matt surface. It is however probable that

many of the better pieces, which now appear to have a matt surface, were originally burnished.

(2) *Graphically*: This was done in three ways,—(a) by the use of incised lines, (b) stylus impressions, and (c) comb or stamp marks. With one exception, all the pieces under review had been decorated by either one or by a combination of these methods, all of which were carried out on the wet clay before burning. The stylus used was commonly rounded, and the impressions were either spaced at intervals (No. 16), or used to form continuous lines (Nos. 5, 7, etc.). An angular stylus was also used, as last described (No. 12), and to enhance incised lines (No. 14). The comb was used on three pieces, Nos. 14, 15, and 16. In the case of No. 13, a coiled strand of twisted wire appears to have been used in the decoration of the rim-band.

(3) *Coloured Infilling*: It was noted that in one instance incisions, and in another, comb marks (No. 14), had been filled in with a deep red pigment.

(4) *Moulded Decoration*: The only features which we can include under this head are the rolls with which the lips of pots Nos. 1 and 2 are finished, and the rim-band of pot No. 13.

DISCUSSION.

(1) UNUSUAL FEATURES: This pottery presents us with a number of striking features, which although they are known individually from different indigenous wares, have not been previously recorded as occurring in one industry. We may signalise the following features, viz.:—

(*a*) *The Spouts*: Two sherds, each of which showed the base of a spout, and one complete decorated spout (No. 4) were recovered. Tubular spouts, such as ours, have been found over a wide area of South Africa, in pottery which belongs to both a Bantu and a Hottentot facies, but they were only found in any number at Mapungubwe, on which site however, all the examples were undecorated (Ref. No. 3, pl. xxx). We may therefore recognise the use of the decorated spout as being one of the distinctive features of the Bambata pottery industry.

(*b*) *The Crenellated Edge*: Pottery with notched or crenellated edges has been recorded from the Zeerust district of the Transvaal (Ref. No. 4), from the Coastal Sites of Natal (Ref. No. 5), and from Mapungubwe (Ref. No. 3, pl. xxvii, 17), where a solitary piece was found amongst all the thousands of sherds which were examined. At Bambata the crenellation was carried right over the edge of the pot and was combined with the decoration of the rim and neck, in a manner which we can recognise as being another of the distinctive features of this industry.

(*c*) *Stylus Impressions*: The use in decoration of lines formed with the contiguous impressions of a rounded stylus, is another feature which has not been recorded before, as is also the practice of enhancing incised lines with stylus impressions.

(*d*) *The Hollowed Lip*: Several pieces, of which the most definite is No. 11, show a hollowing of the interior surface of the lip. We have noted this feature on pottery from Gokomere and other sites which have yielded Class R_1 wares, but up to the present it has not been recorded from any other pottery industry.

(*e*) *The Coloured Infilling*: The use of coloured infillings to embellish the decorative detail of their pottery, is a common device of modern Native potters. The practice appears to have been recorded only once previously from an archaeological site, when a sherd from Haddon was found with an incised design which had been filled in with a black substance (Ref. No. 3, pl. xxxiv, 39).

(2) COMPARATIVE MATERIAL: In addition to the instances mentioned above, the following sites have yielded material which resembles our pottery to a greater or a less degree.

Uqapu: A sherd from this Zululand site recapitulates in an attenuated form, all the salient features of our sherd No 1, for the notched roll and the alternating vertical and horizontal lines are all present (Ref. No. 5, Fig. 1, 4). It would seem that any direct connection between these two wares is precluded by both time and space, nevertheless, the resemblances are very striking.

Zimbabwe, Echo Farm and other Sites: The most striking instance of relationship with pottery from other sites is provided by our sherd No. 13, for there can be no question, but that it belongs to that very widely diffused Class R_1 pottery, which Caton-Thompson was the first to describe from Zimbabwe (Ref. No. 1, p. 25). Since then this pottery has been found at the Echo Farm and Commonage Sites near Salisbury, Arcturus, Madiliyanga, Gokomere, and in the Moanza Cave, Umtali.

The importance of this identification does not lie only in the fact that Class R_1 pottery has been found throughout the length and breadth of Southern Rhodesia, but also that in several instances, such as the Cave and Tunnel Sites at Gokomere, and in the case under review, it was lying directly on strata containing Wilton artifacts. As Father T. Gardner put it in describing the Gokomere Sites, "Above that level there were no Stone Age artifacts, and below that level there was no Iron Age pottery." These remarks apply with equal force to the conditions at Bambata, where our sherd No. 3 was directly superimposed on the Wilton material, while the Class R_1 sherd, No. 13, was at the same depth.

The relationship which must have subsisted between our wares and the Class R_1 pottery is still further demonstrated by the fact that the two techniques were combined in our No. 14, and perhaps in Nos. 15 and 16 as well, for all these fragments were decorated with stamped impressions.

Toupye Kopje Bechuanaland: Sherds Nos. 15 and 16, may on the other hand, represent the intrusion of yet another alien pottery industry, for vessels with vertical necks and decorated with comb marks, all of which are very similar to our pieces, have been found on several sites, and notably at Toupye Kopje in Bechuanaland. None however, which we have seen, have the rims decorated in a manner similar to the pieces from Bambata.

(3) EVIDENCE AS TO THE MAKERS OF THE CLASS R_1 AND THE BAMBATA POTTERY: We have unfortunately, no direct evidence which would enable us to identify the tribe that was responsible for the manufacture of Class R_1 pottery, even if such tribe continues to exist, but it is not improbable that it belonged to a branch of the Sotho group of the Bantu people. Our reasons for making this suggestion are as follows:—

(a) The Sotho were unquestionably the first of the Bantu peoples to cross the Limpopo River into the Transvaal (Ref. No. 7, p. 333), and it is reasonable to suppose that they were therefore amongst the first Bantu to occupy Southern Rhodesia.

(b) The Sotho still make use of the comb in the decoration of their pottery. This is also a distinctive trait of the Class R_1 wares.

(c) Pottery, which seems to us to be intermediate between modern Sotho pottery and our Class R_1 wares, has been found in the northern Transvaal. and also at Aasvoelkop, near Johannesburg.

Our information regarding the makers of the Bambata wares is even more scanty than is the case with the Class R_1 pottery. Nevertheless we would put forward the following points which may help to clarify the issue:—

(a) The stream of South African ceramics flows in two main channels, namely the Bantu and the Hottentot traditions.

(b) None of the characteristic Hottentot traits occur at Bambata. Amongst these traits we would enumerate, (1) The pointed base, (2) The thin well burnt fabric, and (3) The horizontally pierced lug with internal reinforcement (Ref. No. 8).

(c) On the other hand, all the characteristic features of the Bambata wares occur in pottery of a Bantu facies.

We would therefore suggest that the makers of the Bambata wares were a people who enjoyed a similar form of Bantu culture to that possessed by the makers of Class R_1 pottery, who were themselves, in all probability members of the Sotho group of the Bantu peoples.

On stratigraphical grounds, it is evident that the makers of both of these classes of pottery were amongst the earliest Bantu people to occupy Southern Rhodesia.

(4) Historical Summary: We must not, of course, regard the Bantu occupation of Southern Rhodesia as being a single event. Rather we should see in it a series of invasions and raids, of a more or less isolated character, which were carried out on the more desirable parts of the country, by different though probably related sections of the Bantu peoples. We may at least tentatively identify the people who were in the vanguard of these invasions, as being, in part at least, ancestral to the Sotho peoples of the Transvaal.

We believe that these people brought with them the well developed pottery traditions, the products of which we have been discussing. From the evidence afforded by the Limpopo Sites it is also probable that they reared short-horned cattle, sheep and goats; cultivated millet and beans; smelted iron and copper: in short, they were possessed of all the essential material elements of Bantu Culture as we know it to-day (Ref. No. 3).

Generally speaking the effect of these invasions on the original inhabitants would be to restrict them more and more to the deserts and the mountain fastnesses. We have learned from the skeletal remains found at Mapungubwe (Ref. No. 3) that these people were by no means exterminated, but on the contrary, whole communities adopted the salient features of the Bantu Culture. Nor was the exchange entirely one-sided, for to this day the Sotho and the Nguni peoples retain the clicks which they acquired from their predecessors. Besides this, the long tanged, triangular pointed iron arrowheads found at Zimbabwe and Mapungubwe (Ref. Nos. 1 and 3), are directly derived from the arrow with a detachable foreshaft, which was used by both the Bushman and the Hottentot. It is therefore probable that the Venda and other Bantu peoples who use the bow, derived it from that source. While the more widespread use of the bow as a musical instrument was due, like the concerted ensembles of reed-flute players, to the Hottentots (Ref. No. 9)

It is at present impossible to fix even an approximate date for the Bantu occupation of Southern Rhodesia. When history opens, with the Portuguese Records, we find the country occupied by the Empire of the Monomotapa, which was already in a state of decay. If we are correct in supposing that this empire represented the culmination of the Shona, as opposed to the Sotho occupation, then it is clear that we must push the latter back for several centuries prior to 1500 A.D. But again we must not lose sight of the haphazard nature of the whole process, for it is altogether likely that Sotho influence was still extending to fresh spheres, in out of the way places, long after the main body had advanced far to the south, for it appears probable that isolated communities, like that at Gokomere continued to occupy the same territory, from which they had evicted the Stone Age inhabitants, right down to modern times.

A SUMMARY OF CONCLUSIONS.

We believe that our argument will support the following conclusions:—

(1) That the upper archaeological stratum at Bambata Cave, which rested directly on a stratum containing Wilton

artifacts, contained pot sherds which belong to a hitherto undescribed pottery industry.

(2) That this pottery indicates that it was made by a people who enjoyed a form of Bantu Culture.

(3) That these people succeeded the earlier inhabitants without any marked interval of time.

(4) That this occupation was contemporary with that of other sites which have yielded Class R_1 pottery, which was probably made by a branch of the Sotho people.

(5) That it is probable that a mediaeval date should be assigned to this pottery from Bambata Cave.

NOTE ON A BEAD.

A solitary bead was recovered from the upper stratum. It measures 8 x 10.5mm, it was made of wound glass, but it is so badly decayed that it is impossible to divine its original colour, at present it is a dull opaque white and slightly iridescent. In our opinion, beads are seldom found on Rhodesian sites which are earlier than the middle of the 17th century. The fact that only one bead was found at Bambata, tends to confirm our view as to its early date.

A DESCRIPTION OF THE TEXT FIGURE.

(1) A fragment of the rim of a pot, probably more or less spherical, and about 9 inches over the rim. In a black clay with a dark brown matt surface. The mouth was finished with a bold roll which was decorated with fine transverse lines which had been incised on the wet clay. The neck had a series of roughly parallel lines which had been made in a similar manner. These were divided by vertical lines, probably at intervals. Part of the pot seems to have been subjected to secondary burning.

(2) A fragment of the rim of a pot of which the mouth was about 6 inches over the rim. In a fine grey clay with a buff matt surface. The mouth had a bold roll, flattened on the top, undercut externally and finished with a rippled surface.

(3) A fragment of the rim of a large bowl, about 9 inches in diameter. In a coarse black clay finished with a matt or a burnished surface. The rim was rounded and slightly everted, and was decorated, before burning, with transverse

lines on its interior and exterior aspects. From a depth of 4′ 6″ beneath the surface.

(4) A fragment of the rim of a pot, probably more or less spherical, with a spout. The mouth was about 7 inches across. The clay was coarse, dark brown and had a matt finish. The rim was rounded and surrounded by a band formed with four lines of diagonal incisions the uppermost of which had been taken right over the rim to form a crenellated edge. The spout seems to have sprung from below this band. The nozzle was irregular, and had been decorated with lightly incised diagonal hatching, below which there were three lines of rounded impressions.

(5) A fragment of the rim of a bowl or of a beaker, about 6 inches in diameter. In a fine grey clay with a greyish buff matt surface. The rim was rounded and the edge had pairs of point or comb marks. Directly below the rim there was a wide band which had been formed successively with two lines of round shallow impressions, a band of diagonal cross hatching and five lines of rounded impressions. All had been done on the wet clay.

(6) A fragment of the rim of a shallow bowl, about 11 inches in diameter. The clay, the finish and the decoration were all very similar to No. 4, above.

(7) A fragment of the rim of a pot with a flared neck, about 6 inches over the rim. The clay and the finish were both very similar to Nos. 4 and 6, but was somewhat finer. The lip was hollowed a little on the inside. The rim was decorated with a line of rounded vertical incisions, which had been taken right over the rim to give it a crenellated edge. The neck was concave, and decorated with four lines of rounded impressions, below these was a deep band of vertical and horizontal lines. All had been done on the wet clay.

(8) A fragment of the rim of a pot with a contracted mouth. In a grey clay with a worn surface. The rim was rounded, and directly below it there were two incised lines and a wide band of diagonal cross hatching. All of which had been done on the wet clay.

(9) As the last, but in a buff clay with a buff matt surface, probably the result of secondary burning. The rim was squared and decorated with diagonal grooves. Below the rim there was a band of wide diagonal lines, below which there was a line of rounded impressions.

(10) A fragment of the rim of a larger and coarser pot similar to No. 7 above. The notches of the rim were rather deeper. The decoration was done in a very rough manner on the wet clay.

(11) A fragment of the rim of a pot with a flared neck, about 8 inches over the rim. The clay and finish were very similar to the last. The rim was crenellated, directly below it there was a wide band of diagonal cross hatching, below which there were several deeply incised horizontal lines. All the decoration had been cut on the wet clay.

(12) A fragment of the rim of a large bowl. In a grey clay with a black burnish externally and a brindled matt surface internally. The rim had been rounded, and below it there were three inclined lines of deep stylus impressions.

(13) A fragment of the rim of a large shouldered pot, about 7 inches over the rim. In a blackish clay with a brick red matt surface. The rim was finished to a ridge, the rim-band was convex, and had been decorated with deep diagonal impressions, which seem to have been made with a coiled strand of twisted wire. The neck was concave, and irregular double lines had been scratched on it at intervals of about an inch. All the decoration had been made on the wet clay. Found at a depth of 4′ 6″ below the surface.

(14) A fragment of the rim of a pot with a flared neck about 4 inches over the rim. In a coarse grey clay with a brindled matt or burnished surface. The rim was rounded and below it there was a wide band of vertical lines of comb marks, below this band there were seven deeply incised lines over which stylus impressions had been made. The impressions on the neck-band had been filled in with a deep red pigment. All the decoration had been done on the wet clay.

(15) A fragment of the rim of a pot with a vertical neck, about 5 inches over the rim. In a coarse buff clay with a matt surface externally and smoothed internally. The rim was cut square and decorated with diagonal comb marks. Below the rim there were successively two lines of comb marks, a band of diagonal comb marks, and four lines of comb marks, all of which had been done in a very rough manner.

(16) A fragment of the rim of a pot with a vertical neck. In a black clay with a worn surface. The rim was flattened and rounded, and had a line of shallow impressions on its inner aspect. Below the rim there were successively three lines of impressions and a band of diagonal comb marks.

Note on the Above Paper by Rev. Neville Jones.

This short paper describes the pottery found at Bambata Cave in the Matopo Hills, Southern Rhodesia, during the excavations made by Neville Jones in 1939 and earlier. It belongs to a hitherto undescribed pottery industry and was found in the uppermost archaeological stratum directly above the Wilton.

While there is no direct evidence as to the makers, the writer is of opinion that they were a branch of the Bantu people. Stratigraphical evidence indicates that the pottery makers succeeded the earlier inhabitants without any marked interval of time, and it appears probable that they were contemporary with the people who made Class R_1 (the earliest Rhodesian pottery hitherto known). He therefore assigns a mediaeval date to this pottery.

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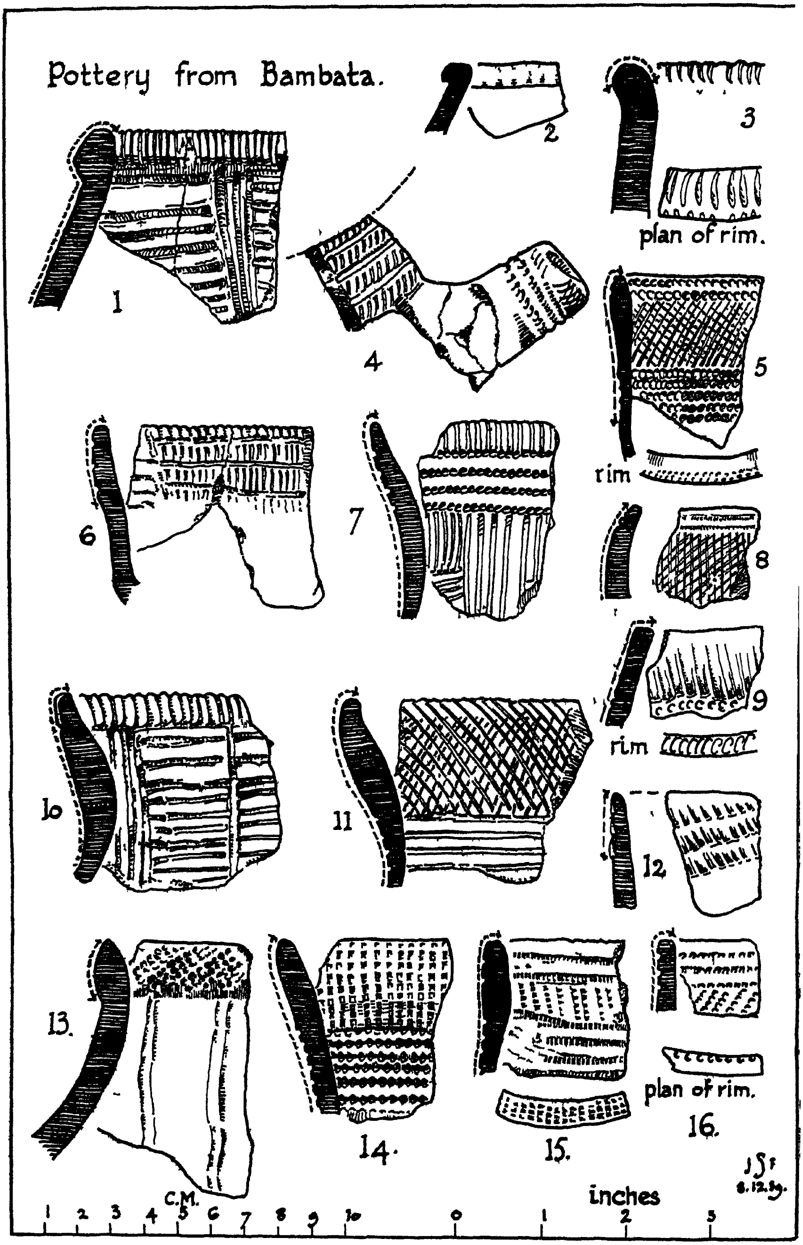
Pottery from Bambata.
1
2
3
plan of rim.
4
5
rim
6
7
8
9
rim
10
11
12
13.
14.
15.
plan of rim.
16.
JSF
8.12.29.
C.M.
1 2 3 4 5 6 7 8 9 10
inches
0 1 2 3

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February, 1941.

THE PARETO LAW AND THE DISTRIBUTION OF INCOMES IN SOUTHERN RHODESIA

BY

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Presented July, 1940.

Pareto's law is classed by statisticians among a number of mathematical formulae known as empirical frequency equations. Such laws are based on no known logical foundations but represent with a high degree of accuracy the mathematical relationships repeated experiments have shown to exist between certain statistical frequency groups. Examining the statistics of incomes in a number of countries Professor Pareto stated in his "Cours d'Economie politique" that there is a simple law which governs the distribution of incomes in all countries and at all times.

In its simplest form Pareto's law may be expressed mathematically as follows:—

$$y = \frac{A}{x^a} \qquad (1)$$

where A and a are constants to be determined from statistics of incomes and y is the aggregate number of incomes at or above £x. Taking the logarithm of this expression gives

$$\log y = \log A - a \log x \qquad (2)$$

If this expression be plotted with Cartesian co-ordinates the resulting graph is a straight line sloping downwards from left to right with a gradiant a. If the above expression be differentiated the following formula is obtained

$$\frac{dy}{dx} = \frac{Aa}{x^{a+1}}$$

Writing $\frac{dy}{dx}$ as y the expression becomes

$$y = \frac{Aa}{x^{a+1}}$$

where y represents the number of incomes at £x, a form of Pareto's law which is less common than the former. If the logarithm of this equation be taken the expression becomes

$$\log y = \log Aa - (a+1) \log x \qquad (4)$$

a linear expression whose graph slopes downwards from left to right as in the more common form of the law. The objects of the present paper are to determine the parameters of this equation from the published statistics of the distribution of individual incomes in Southern Rhodesia, and to discuss the limitations of the law. In order to interpret the significance of the results it is necessary to obtain a clear conception of the scope of the official Income tax statistics. It is proposed to utilise the published returns relating to the year 1936/37 since this will enable the law to be examined in the light of the results of the census of population 1936.

SCOPE OF THE SOUTHERN RHODESIA INCOME TAX STATISTICS IN 1936.

The scope of the official returns in 1936 is clearly described in a thesis submitted to the University of South Africa by Mr. K. V. W. Nicholls for the Degree of Master of Arts entitled "The Public Finances of Southern Rhodesia during the first ten years of responsible government." The statistics which approximate most closely to the commonly accepted conception of income in the Annual Report of the Commissioner of Taxes are termed taxable incomes. Taxable income is the total amount other than receipts or accruals of a capital nature received by, or accrued to, or in favour of any person in any year less the following principal amounts:

(a) Losses and outgoings actually incurred in the production of the income, provided they are not of a capital nature.

(b) Sums expended for the repairs of property occupied for the purpose of trade or in respect of which money is receivable

(c) Reasonable allowance for wear and tear of machinery, implements and other articles used by the tax-payer for the purpose of his trade.

(d) In respect of income from mining operations, an allowance for the redemption of capital expenditure in lieu of the allowances for wear and tear.

(e) Income exempt from taxation. The most important of the items in this class are dividends and interests on debentures or debenture stock received or accrued from any company chargeable with income tax in the Colony, income on which tax has already been paid in the Colony, the revenues of local authorities. building and friendly societies, co-operative agricultural societies with limited liability, the interest on Post Office Savings Bank deposits and on tax exempt loans. (See K.V.W. Nicholls p. 99.)

In 1936 in Southern Rhodesia, as in the Union of South Africa, it was the source of income rather than the residence of the recipient that determined liability to income tax. Statistics of taxable incomes therefore related to incomes originating within the Colony regardless of the residence of the recipient and excluded incomes from overseas received by residents in Southern Rhodesia. The application of Pareto's law in both countries in 1936 is thereby restricted to describing the distribution of incomes originating within the boundaries of the respective territories and not that of the actual incomes possessed by the inhabitants of the two countries. In applying the formula derived from the income tax statistics to the results of the census of population in 1936, the assumption is made that the number of incomes originating in the Colony and payable outside is equal to those originating in other countries and received by Southern Rhodesia residents and that the number of incomes originating in the Colony therefore approximates to the number of recipients resident in Southern Rhodesia. The further assumption is made that the number of gainfully occupied population is roughly co-extensive with that of income recipients resident in the country.

The abatement for single persons was £360 and for married £800. Owing to family allowances it is considered that the statistics of taxable income fail to embrace all individual incomes below the level of £1,100 a year. In order to obtain results applicable to all incomes originating in the Colony in 1936, it is therefore necessary to apply the law to incomes of £1,100 a year and over.

DETERMINATION OF THE CONSTANTS.

In applying any mathematical formula to statistical data the method of fitting the curve is of great importance. Professor Pareto used the method of least squares. Professor Bowley advocates three methods of fitting the curve. The first involves plotting the points on double logarithmic paper, approximating to the straight line and selecting two points on this line from which the gradient can be determined. The second method is derived from (i) the ratio of the number of incomes between £x_1 and £x_2 to the number between x_1 and x_3, and (ii) mathematical formulae for the number of incomes within these limits. (1) The ratio is obtained from the income statistics and then the constant *a* in the mathe-

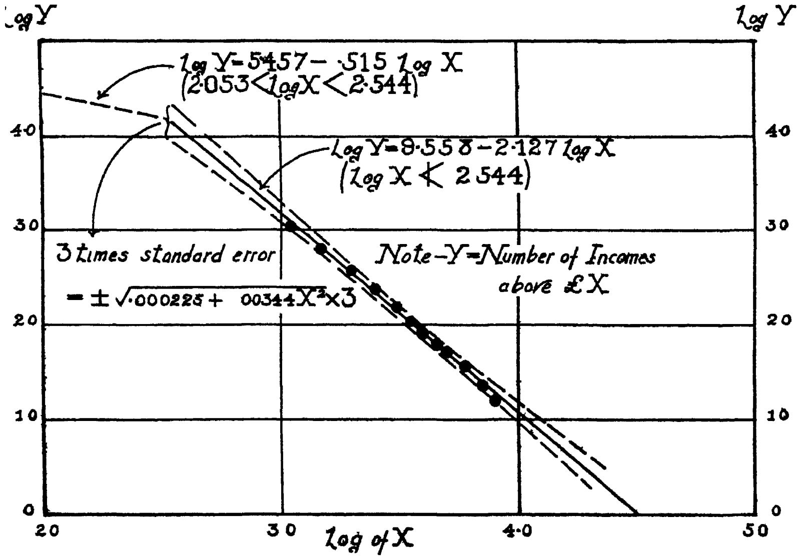

Diagram I — Pareto's Curve for all Incomes in Southern Rhodesia 1936

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(1) Number of incomes above $x_1 = \dfrac{A}{x_1{}^a}$ and number of incomes above $x_2 = \dfrac{A}{x_2{}^a}$.

The number of incomes between £x_1 and £x_2

$$= \frac{A}{x_1{}^a} - \frac{A}{x_2{}^a} = A\left\{\frac{1}{x_1{}^a} - \frac{1}{x_2{}^a}\right\}$$

Ratio of number of incomes between £x_1 and £x_2, and £x_1 and £x_3

$$= \left\{\frac{1}{x_1{}^a} - \frac{1}{x_2{}^a}\right\} \div \left\{\frac{1}{x_1{}^a} - \frac{1}{x_3{}^a}\right\}$$

matical formula which will give the nearest approximation to the ratio is obtained by successive trials and interpolation. The third method which Professor Bowley considers uses the data more completely is obtained from the following formula(2).

Average income in the range x_1 to x_2

$$= \frac{a}{a-1}\left\{\frac{1}{x_1{}^{a-1}} - \frac{1}{x_2{}^{a-1}}\right\} \div \left\{\frac{1}{x_1{}^{a}} - \frac{1}{x_2{}^{a}}\right\}$$

The value of a can be determined either by graphical methods or by successive trials and interpolation. In order to compare the results all four methods will be employed in the present paper, but the method of least squares is perhaps the most convenient way of fitting the curve since it also provides a mathematical means of determining the standard error of any estimates based on the mathematical equation.

The constants obtained by the four methods outlined above are given below:—

Method 1. $\log y = 8{\cdot}969 - 1{\cdot}954 \log x$
2. $\log y = 8{\cdot}836 - 1{\cdot}910 \log x$
3. $\log y = 8{\cdot}994 - 1{\cdot}959 \log x$
4. $\log y = 9{\cdot}558 - 2{\cdot}127 \log x$ (see Diagram I)

where y = the number of incomes above £x and x equals any given income. Method 4 which utilizes the method of least squares provides a means whereby the theoretical error in the estimate can be determined. The standard error of $a = \frac{s}{\sigma x \sqrt{n}}$ where s is the standard error of the estimate and σx the standard deviation of x. This formula gives standard error of a = ·0586. By a mathematical convention errors which differ by more than three times the standard deviation can be regarded as fortuitous since the probability of getting such a difference in samples selected from the same universe is 370 : 1 against. By this criterion the estimates obtained from the first two differ significantly from those obtained by the last two methods. The method of least squares may be regarded as the best estimate of the linear relationship between the observations involved, and methods 1 and 2 are therefore seen to give unsatisfactory results.

VALIDITY OF THE LAW.

The *range of validity* of Pareto's law does not usually extend to very high and very low incomes. In Southern Rhodesia the total gainfully occupied population in 1936 was 25,111. Utilising this value in formula (4) gives log x=2·425 whence x=£266 In other words there were 25,111 incomes above £266 in 1936 It seems highly probable that the lowest income earned by the 25,111 persons was below £266. It may therefore be concluded that the mathematical expression for the law relating to the distribution of incomes in Southern Rhodesia in 1936 does not apply to the lower income levels. Examination of a graph of the expression shows that the law holds at least over the range £1,101 to £6,500, and provides a fairly good approximation at higher income groups. No method has so far been devised whereby the limit of the range of validity of the law can be definitely determined, but it is hoped that with the extension of the income tax limits to lower ranges further light on this subject will be obtainable in the course of the next few years.

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(2) Since $y = \frac{Aa}{x^{a+1}}$ is the equation showing the number of incomes at £x, the aggregate income at £x = £xy. The aggregate value of incomes between

$$£x_1 \text{ and } £x_2 = \int_{x_1}^{x_2} xy\,dx = \frac{Aa}{a-1}\left\{\frac{1}{x_1^{a-1}} - \frac{1}{x_2^{a-1}}\right\}$$

The number of incomes in the range £x_1 and £x_2

$$= A\left\{\frac{1}{x_1^{a}} - \frac{1}{x_2^{a}}\right\}$$

∴ Average income in the range £x_1 to £x_2

$$= \frac{Aa}{a-1}\left\{\frac{1}{x_1^{a-1}} - \frac{1}{x_2^{a-1}}\right\}$$

$$\div A\left\{\frac{1}{x_1^{a}} - \frac{1}{x_2^{a}}\right\} = \frac{a}{a-1}\left\{\frac{1}{x_1^{a-1}} - \frac{1}{x_2^{a-1}}\right\}$$

$$\div \left\{\frac{1}{x_1^{a}} - \frac{1}{x_2^{a}}\right\}.\ \text{Q E.D}$$

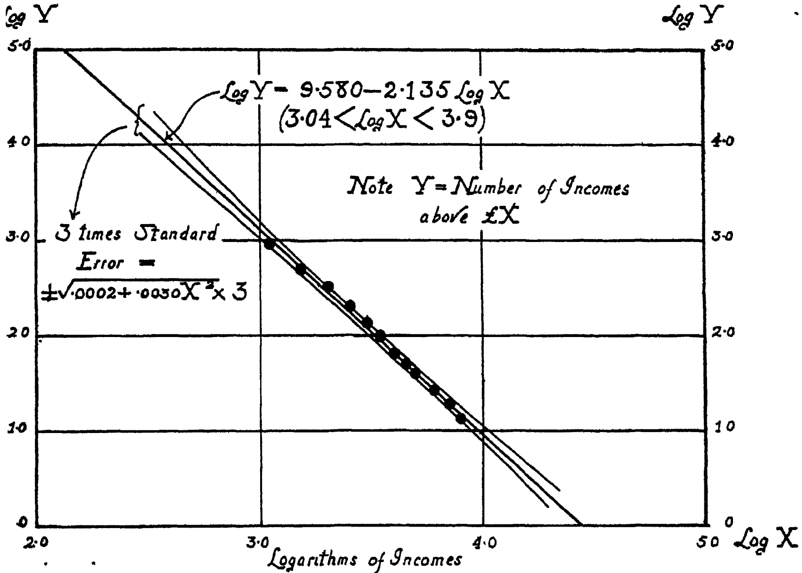

Diagram II Pareto's Curve for married persons

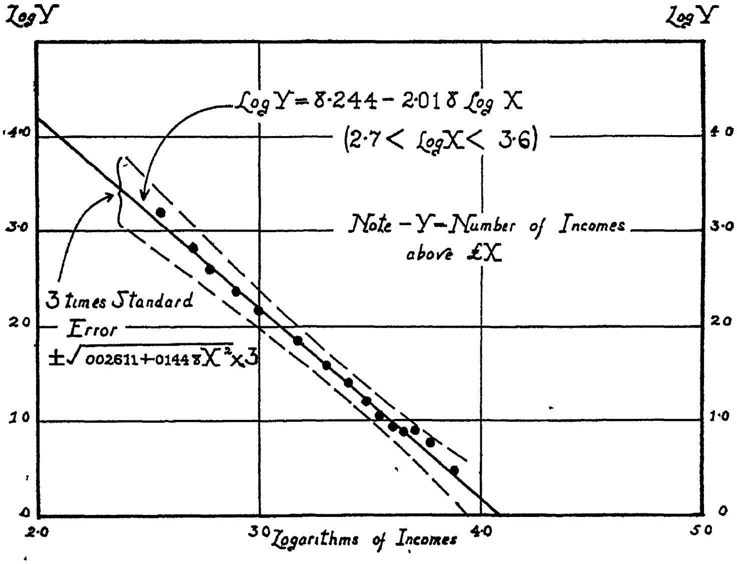

Diagram III − Pareto's Curve for non-married persons

Sectional Validity: To what extent is the law applicable to income groups within the community such as the distribution of incomes between married and "other" persons? If the mathematical formula be fitted by the method of least squares to the statistics of incomes of married and of not married persons the following formulae are obtained:

Married—$\log y=9{\cdot}530-2{\cdot}135\ \mathrm{Log}\ x$ (see Diagram II)

Others.- $\log y=8{\cdot}244-2{\cdot}018\log x$ (see Diagram III)

Owing to abatements etc., the statistics of married persons' incomes are not fully included until incomes exceed £1,100, and in the formula for married persons all incomes above £1,500 have been utilised. Of the other persons, all incomes have been employed.

According to the census of population the number of unmarried gainfully occupied persons in the country in 1936 was 12,521. Substituting this value in the expression for "unmarried persons" gives $\log x=2{\cdot}051$, $x=$ £114. This is a reasonable figure for the lowest income received by unmarried persons, and it would appear that the expression is approximately correct in the lower income ranges of unmarried persons. The number of married persons in receipt of salaries in 1936 was 12,590 (i.e. 25,111 gainfully occupied persons less 12,521 unmarried persons). By the method utilised above the lowest income of the married persons becomes £349. The income of unmarried persons may easily be as low as £114, and the figure of £349 for married persons is by no means fantastic.

The number of incomes above £x less the number of incomes of non-married persons above the same level should

Estimates.	Total Number of Incomes Above				
	£1,000	£800	£600	£400	£352
1. Total number of Incomes	1,503	2,416	4,455	10,551	13,852
2. Number of Incomes of non-married persons	155	243	434	984	1,274
3. Number of Incomes of married persons (1-2)	1,348	2,173	4,021	9,567	12,578
4. Number of Incomes of married persons (Pareto's law) ..	1,334	2,147	3,967	9.430	12,391

provide an estimate of the number of incomes of married persons. This should agree with the results obtained from using the mathematical expression for the number of incomes of married persons above this level. The same method could be utilised to estimate the number of incomes above £x of unmarried persons, but the results would be less accurate since, owing to the greater variation in the abatements due to married persons, Pareto's curve for married persons is probably less accurate than that for other persons. In the preceding table the number of married persons' incomes in excess of certain incomes has been estimated by the above method and the estimates compared with those obtained from Pareto's law for the distribution of married persons' incomes:

The two independent estimates show a large degree of agreement, but in the lower estimates the difference tends to become increasingly large.

Hypothetical Form of the Law in Southern Rhodesia: The total number of married persons in receipt of incomes has already been estimated at 12,590. The lowest income level is shown by the above method to be roughly £352; by the Pareto law it was shown to be £349. Assuming the correct figure to be between these two figures or in round numbers £350, the distribution of incomes below £350 relates exclusively to that of non-married persons. Assuming the Pareto expression for non-married persons to be roughly correct, the incomes of this class have been shown to extend to £114. Pareto's law for all incomes must therefore extend to as low an income as £114 and not to £266 as given by the mathematical formula for all incomes. The law seems to give consistent results for the distribution of all incomes, for married persons' incomes and for other persons' incomes to as low a figure as £350, and it would therefore appear to assume a gentler gradient from £350 to £114. In this section of the curve are included the remaining incomes of the 25,111 persons gainfully occupied in 1936, all of whom have been shown to be unmarried. From these facts it is possible to deduce the slope of the curve below £350.

The logarithm of the number of incomes above £350 according to the formula is 4·147; that of the 25,111 gainfully occupied persons is 4·400. Since the lowest income limit of the curve after the turning point has been shown to be £114 the slope of the new section of the curve can be determined.

The logarithm of £350 is 2·544 and of £114 is 2·053.

Within a range of ·491 logarithmic units the logarithm of the number of incomes falls ·253 units. The slope of the curve between £114 and £350 is therefore $-\frac{\cdot 253}{\cdot 491}$ or $- \cdot 515$.

From this parameter the constant A for the new section can be determined as follows:— u

$$\begin{aligned} &\text{Log. } 25111 = \log. A - \cdot 515 \log. x \\ \therefore\ &4\cdot 400 = \log. A - \cdot 515 \times 2\cdot 053 \\ \therefore\ &\text{Log. } A = 5\cdot 457 \end{aligned}$$

On this assumption Pareto's law in the income ranges £114 to £350 would therefore appear to take the form $y = 5{\cdot}457 - {\cdot}515 \log x$ (Diagram I). Confirmation of the hypothesis that in Southern Rhodesia the gradient of the formula for Pareto's law changes its slope at log 350 must await the analysis of the statistics provided by the lowering of the income abatements in 1940.

Summary: (1) The distribution of incomes originating within Southern Rhodesia in 1936 can be accurately described by Pareto's law within certain limits. The relevant formulae and the ranges of the independent variable within which the formulae are valid are shown below:—

(i) All incomes. $\log y = 9{\cdot}558 - 2{\cdot}127 \log x$ $(3{\cdot}3 < \log x < 3{\cdot}9)$.

(ii) Married persons $\log y = 9{\cdot}530 - 2{\cdot}135 \log x$ $(3{\cdot}04 < \log x < 3{\cdot}9)$.

(iii) Other persons. $\log y = 8{\cdot}244 - 2{\cdot}018 \log x$ $(2{\cdot}7 < \log x < 3{\cdot}6)$.

(2) The available evidence suggests that the formula for all incomes changes its gradient at £350 and can therefore be utilised only in respect of incomes exceeding £350.

(3) Below £350 the following hypothetical expression for Pareto's law is deduced:—

$$\log y = 5{\cdot}457 - {\cdot}515 \log x \ (2{\cdot}053 < \log x \nless 2{\cdot}544)$$

(4) The hypothetical formula for the distribution of incomes in Southern Rhodesia is as follows:—

$$\log y = 9{\cdot}558 - 2{\cdot}127 \log x \ (\log x < 2{\cdot}544)$$
$$\log y = 5{\cdot}457 - {\cdot}515 \log x \ (2{\cdot}035 < \log x < 2{\cdot}544).$$

APPENDIX.

TABLE I.—DISTRIBUTION OF ALL INCOMES AND MARRIED PERSONS' INCOMES IN SOUTHERN RHODESIA, 1936.

Income Limit	Log. of Income Limit	All Incomes.		Married Persons' Incomes	
		Number above Income Limit	Log. of Number above Income Limit	Number above Income Limit	Log. of Number above Income Limit
1,101	3·0418	1,061	3·0257	935	2·9708
1,501	3·1764	588	2·7694	521	2·7168
2,001	3·3012	382	2·5821	340	2·5315
2,501	3·3981	237	2·3747	211	2·3243
3,001	3·4772	160	2·2041	144	2·1584
3,501	3·5442	109	2·0374	98	1·9912
4,001	3·6022	78	1·8921	69	1·8388
4,501	3·6533	63	1·7993	55	1·7404
5,001	3·6991	49	1·6902	41	1·6128
6,001	3·7783	36	1·5563	30	1·4771
7,001	3·8452	23	1·3617	20	1·3010
8,001	3·9052	15	1·1761	14	1·1461

TABLE II.—DISTRIBUTION OF NON-MARRIED PERSONS' INCOMES IN SOUTHERN RHODESIA, 1936.

Income Limit	Log of Income Limit	Number above Income Limit	Log. of Number Above Income Limit
360	2·5563	1,651	3·2178
501	2·6998	657	2·8176
601	2·7789	399	2·6010
801	2·9036	232	2·3655
1.001	3·0004	160	2·2041
1,501	3·1764	67	1·8261
2,001	3·3012	42	1·6232
2,501	3·3981	26	1·4150
3,001	3·4772	16	1·2041
3,501	3·5442	11	1·0414
4,001	3·6022	9	·9542
4,501	3·6533	8	·9031
5,001	3·6991	8	·9031
6,001	3·7783	6	·7782
7,001	3·8452	3	·4771
8,001	3·9032	1	—

Source—Annual Report of Commissioner of Taxes for the year ended 31st March, 1938.

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A SURVEY OF PHYSICAL EFFICIENCY IN SOUTH AFRICA

BY

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Read 1 July, 1940.

The subject matter of this paper, which is based on an extensive experimental survey, is divided into four parts. Of these we intend to deal mainly with the first, in which the growth of working efficiency in various racial and other groups of the South African population, as well as certain dietary problems of labour, will be discussed in some detail The main points of parts 2, 3 and 4 of our work will only receive brief consideration in this publication. Our evidence, especially our figures, tabulated results of our statistical analyses, numerous diagrams and photographs, our final conclusions, as well as our bibliography, will be presented in full in a monograph which is now under preparation.

In the second part of this paper attention will be drawn to the fact that the standard of physical efficiency of the South African youth is not satisfactory.

In the third part reference will be made to a quantitative assessment of the improvement of physical working power, as can be induced by means of organised physical training In the last part of this communication certain conclusions will be drawn. It will be suggested that the state should insist upon specified levels of physical efficiency being attained by every school-going youth in the country; that the necessary measures must be provided by the authorities to ensure the success of such an educational scheme.

Lastly, short reference will be made to an attempt to assess quantitatively the economic value of physical education. This attempt has as its aim the elaboration of organised labour schemes with a view to making use of what should be regarded as a permanent state of mobilisation of the working resources of the country.

INTRODUCTION.

In this preliminary report a summary will be given of investigations of the physical efficiency of South African youths which have been conducted during the last two years. Although one of our ultimate aims was to define the part played by nutritional factors, it was necessary first to ascertain actual standard values of physical working power. This appeared to be essential since a review of the literature has shown that very little experimental work has been undertaken with regard to this question. Experiences with competing athletes indicate that the standard of physical performances could be influenced by nutritional measures. The potentialities of dietary regimes with regard to physical prowess have, however, frequently been overestimated since they have rarely been specifically studied.

The significance of physical education has never before been clearly assessed from the point of view of public health or economy. This is a shortcoming which is due to the fact that physical education is a young science. Only now has the stage been reached when quantitative studies can be undertaken. It must be realised that without a quantitative assessment of human efficiency our educational aims with regard to physical training cannot clearly be stated, and that the economic value of physical education has thus remained an unknown quantity. It appears that by introducing the quantitative method we have now reached a point from which we can define the place of physical training in education, as well as its significance from the point of view of economy.

PART I. METHODS AND PRELIMINARY RESULTS.

Physical efficiency is a complex term, embracing different biological spheres of functional significance. Only during recent years have attempts been made to present a physiological classification of our knowledge of the subject. In 1934 A. H. Steinhaus of Chicago, in a monograph on "The Chronic Effects of Exercise," suggested that the physiological results of physical training could be classified in three groups:—

1. Those affecting the organs involved in the oxygen supply of the body, that is, blood circulation and respiration.
2. Those affecting the central nervous system.
3. Those affecting the muscular system.

At the 1937 Annual Meeting of the South African Association for the Advancement of Science, in Windhoek, a paper in which Steinhaus's theory was further developed, was presented (Jokl). It was shown that Steinhaus's classification was suitable not only from the viewpoint of physiology, but that it also indicated the degree of functional representation of the three performance components in various forms of exercise: endurance, skill and strength. Methods were accordingly based for our performance survey on the above theory.

The next step, therefore, had to be the elaboration of practical tests which could reasonably be expected to give an insight into the functional abilities of the three physiological systems involved in physical performances. Suitable and simple tests of endurance, skill and strength had to be devised. At the same time we had to bear in mind that the experiments had to be arranged in such a way as to be applicable without complicated equipment or special technical arrangements.

The simplest test of *endurance* is running over an extended distance. Preliminary investigations showed us that 600 yards is the longest distance which untrained and unselected school children of all age groups are able to run. Originally we intended to use a one mile running race as a test. However, we found that only few children were able or willing to run such a long distance. The simplest test of *skill* is sprinting, as has recently again been shown by Simonson, and by Stetson and Hubbard. That *putting the shot* is a suitable test of *strength* has been known for some time. Corroborative evidence in regard to the last point has recently been presented by Jokl and Suzman (1940), (see below).

The same tests were applied to children and youths between the ages of four and twenty. This procedure was adopted in order to obtain comparable results.

The following groups have been tested to date:—

1. *European Children.*
   - (a) Poor European Children (Pupils of Primary School in George, Cape.) (Approximately 3,000 tests).
   - (b) European Children coming from generally satisfactory environment. Pupils of Secondary School, George, Cape). (Approximately 500 tests).
   - (c) Jewish Children. (Pupils of the Government School, Doornfontein, Johannesburg). Approximately 1,500 tests).
2. *Bantu Children.*
   - (a) Native Schools (St. Augustine, Mafeking and Casino), Nkutu, Zululand. (Approximately 1,600 tests.)
   - (b) Mission School, Shawbury. (Approximately 660 tests).
3. *Chinese Children.*

   Chinese Government School, Johannesburg. (Approximately 300 tests).
4. *Indian Children.*

   St. Aiden's School for Indian Children, Durban. (Approximately 3,000 tests).
5. *Coloured Children.*

   Battswood Primary and Secondary Schools, 'Ottery Road, and Palmerton School, Cape Town. (Approximately 4,000 tests).

The tests were carried out with the assistance of students of the Department of Physical Education of the Witwatersrand Technical College, who had previously received special instruction in the organising, measuring and recording of athletic performances.

A considerable amount of statistical work has been done in order to evaluate the results of the above investigations. Mean performance, standard deviation and standard error of the results have been ascertained and tabulated for each age group. It has thus been possible to obtain age-performance correlations for the various groups examined.

THE HUMAN MATERIAL

Great care was taken to conduct all tests on children who had *not* previously received systematic instruction in physical training. Since there is ample evidence that physical training greatly improves physical efficiency, the tests, if conducted with well trained children, would have revealed a complex picture, made up by the inherent potentialities of the children plus the gain caused by the training. This would have made a proper evaluation of the result impossible. Later in this report, another group of investigations (Jokl and Goedvolk) made on South African boys, will be quoted, in which the influence of physical training is clearly revealed. In this first part of the report, however, we wish to present only standard values of physical efficiency which have not been influenced by the most powerful environmental method to improve them: muscular training.

THE PHYSIOLOGICAL CURVE OF GROWTH OF PHYSICAL EFFICIENCY.

As no similarly extensive survey of normal development of physical efficiency during the first two decades of life has previously been made, it will be necessary to give a short description of the results so far obtained with our standard tests.

Our diagrams clearly reveal a typical rhythm of growth of physical efficiency, irrespective of racial or other factors. Before puberty, the performances in all three tested spheres improve at approximately the same rate. However, even before puberty there is a marked superiority of physical efficiency of the male sex over the female. This is of considerable interest in view of recent information gained on the physiological role of the reproductive glands prior to puberty. It must be stressed, however, that the superiority of physical performances of the males over the females before puberty is clearly marked only if one considers the means taken from large numbers of tests. If scatter diagrams are made for each age group, separately for the two sexes, there is always some overlapping: the best girl athletes beat the worst boy performers.

PUBERTY.

Many of our results suggest that from the viewpoint of physical working power, puberty is a crucial period. In both boys and girls there is a more or less marked retardation in efficiency progress. However, there can be no doubt whatsoever, that while in the case of the boys, puberty acts merely as a retarding force which never interrupts the process of growth of physical efficiency, it is of much greater importance in females. For all practical purposes, it can be said that puberty brings the curve of growth of physical efficiency in women to a standstill; very often it even initiates a period of decline of their working power. This post-puberty decline of female working power has never before been quantitatively analysed. It is of the utmost significance. The decline primarily affects the endurance of the women.

It is remarkable that many text-books on physical training warn us to be most careful with regard to activities demanding endurance in the case of small children. But one has yet to find any reference to the amazing physiological decline of endurance power of girls during adolescence. One was struck by the constantly recurring finding that young children have an endurance power much superior to anything seen in adults. Naturally, the running times of the little ones are not always as good as the record performances of older girls, although even the actual running times of many of the little ones surpass those of the older groups. On the other hand, considering the average performances, it is evident that the small girls are superior to the big ones. It scarcely ever happened that one of the small children (5-8 years) " gave up " during the race. On the other hand there was not a single race for girls of 13 years and older in which not a considerable number discontinued because of " exhaustion," "pain in the side," or other "causes." In many instances only one or two of the approximately twenty girls who started the 600 yards race in each heat finished. Some of the older girls disappeared from the sports grounds as soon as the preparations for the long race began. Furthermore, there was a marked difference with regard to the recovery process *after* the race between the young and the " old." The latter required a much longer time to recover than the former.

The interruption of a steady performance development after puberty in girls is also noticeable, although in a less pronounced way, with regard to sprinting. In no group of girls did we find an increase in the sprinting performances.

Only the shot putt curve continues to climb after puberty. This result is explained by the fact that in untrained individuals this performance is to a considerable extent determined by the factor body weight. This was again shown in a group of adult Bantu in whom a correlation between weight and shot putt performance could clearly be established. This result proves that it is the increase in body weight after puberty which explains the improvement of the girls in shot putt even after puberty. On the other hand it is known that increasing body weight represents a handicap in performances demanding speed and endurance, especially with regard to the latter. The relationship between shot putt and long distance running performances was, therefore, investigated and it was found that wherever the shot putt performances in girls improved markedly after puberty, there was a corresponding decrease in endurance. Thus, in the case of the Indian girls who as a rule do not show an undue gain in weight after puberty, there was little further improvement in the shot putt performances, and accordingly little decrease in endurance power, while in Bantu girls who very frequently " become fat " during and after puberty, the shot putt performances greatly improved, and the 600 yards running performances sharply declined. This result alone strongly justifies our method of testing physical efficiency separately in three spheres of performances. It also shows that there is no strict parallelism between the development of the three physiological systems which determine the state of efficiency with regard to performances of strength, of skill and of endurance. This latter point is impressively emphasised in one of our diagrams, in which three entirely different trends of development are shown to appear after puberty. The shot putt curve climbs, the 100 yards running curve remains more or less on a plateau, while the 600 yards running curve shows a sharp drop. The same diagram again reveals the decisive influence of puberty on efficiency growth. There is an almost complete co-ordination between the pre-puberty development of the three spheres of physical efficiency. Had our observations been based solely on a study of this period, the significance of the three-cornered approach to the problem of efficiency would not have been apparent.

THE PROBLEM OF " ADAPTATION ENERGY " AS APPLIED TO OUR FINDINGS OF THE EFFECTS OF PUBERTY ON EFFICIENCY.

Although we wish to concentrate as much as possible in this preliminary report on the actual results of the investigations, mention should be made at this juncture of Selye's recently presented theory of " adaptation energy." Selye showed that apart from the specific biological defence mechanisms which the body is capable of mobilising in emergency situations, every individual possesses a certain amount of unspecific " adaptation energy " which may become exhausted. An animal is able to overcome the effects of prolonged exhaustive exertion. It can survive a specified period of exposure to extreme heat. It can successfully fight against a well defined threshold dose of atropine. However, the same animal will die if it is compelled to do the same type of exhaustive exercise shortly after having recovered from atropine poisoning. Or it will be killed by the same exposure to heat from which it previously escaped without permanent damage, if the experiment is repeated shortly after finishing the exercise test.

In other words we have to assume the existence of an unspecific factor which enables the individual to cope with emergency situations, provided such emergencies befall the individual as single events. Should several emergency situations arise at the same time, it is possible that permanent damage or even death may be caused by the combination of factors each of which by itself would have been harmless.

There can be no doubt that both puberty and physical activity represent physiological "strains" which are capable of taxing the adaptation energy of the body to the utmost. The fact that we can demonstrate, during puberty, a spontaneous tendency of slowing down or even of a temporary or permanent interruption of the progress of physical working power, must be interpreted as an important biological hint. During puberty unnecessarily strenuous activities leading to physical exhaustion, such as rigid drill as well as other efforts which lay undue stress on the reserve energy of the body, should be avoided. It is obvious that the problem of dietary deficiencies, if viewed as an additional strain occurring during the above period of physiological stress, now assumes a new aspect.

PUBERTY, PHYSICAL EFFICIENCY AND ECONOMIC ENVIRONMENT.

With regard to the experimental facts as presented above, and to their interpretation as given in the preceding paragraph, a group of results of tests obtained from European children of the Primary and the Secondary School at George, Cape, may now be further considered. Without going into sociological details of their environment, it may be mentioned that the families from which the pupils of the George Primary School are recruited, are extremely poor. The assumption can, therefore, be made that their dietary regime is as a whole unsatisfactory. The children of the same age group attending the Secondary School are better off. Their home environment and their food are undoubtedly of a higher quality. It may be assumed that if effects should occur of what is colloquially named malnutrition, on physical efficiency, such effects should reasonably be expected to manifest themselves in individuals whose adaptation energy has already been greatly taxed by the strain of puberty. As evidence had been adduced to the effect that the strain of puberty is greater in girls than in boys, a comparison was made between the results of physical efficiency tests conducted with girl students of the Primary and of the Secondary Schools. Corresponding age groups of girls were examined. The result was most significant. While there was no important difference between the physical efficiency of the primary and of the secondary school pupils *before* puberty, *during and after puberty* the performances of the Secondary School children rather suddenly became superior to those of the Primary School pupils. *We believe that this result represents so far the most important finding of the first part of our survey. If it should be possible to corroborate this, it might be assumed that the post-puberty decline of female working efficiency as demonstrated in various racial groups is, at least partly, due to economic and nutritional influences.*

ANTHROPOMETRIC VERSUS FUNCTIONAL TESTS.

An important result of this experimental survey is the demonstration of the futility of the various anthropometric indices for the assessment of the relationship between nutritional states and working efficiency. Most of those indices which are based on measurements of height, weight, chest expansion, have more recently been used again in comparative investigations of physical fitness. (Souther, 1939, Woofter, 1939). In these studies the utter uselessness of anthropometric measurements in a school health programme was clearly revealed, as is also indicated by our material.

The evidence presented in this report shows that exact physical performance tests are capable of giving us definite information about at least *one* important practical aspect of the applied physiology of nutrition. That such information is greatly needed cannot be doubted. Modern text-books of nutrition abound in statements to the effect that even minor deficiencies in protective food and in other dietary supplies cause a deterioration in working power. As against such statements, too little consideration appears to have been given to an age-old experiment conducted on hundreds of millions of poor workers in all parts of the world, white, yellow, brown and black, who live on bread, potatoes, rice and mealies; attention has been focussed recently on the biological inferiority of such diets. On the other hand it appears to have escaped the notice of most students of the problem that the working efficiency of those poor carbohydrate eaters is very high, not only if considered in the light of their poor diet, but even if it is compared with the physical working efficiency of economically better situated and better fed groups. The same conclusion can be drawn from the results of the extensive study of the effects of Vitamin C on Bantu mine workers, as conducted by Fox, Dangerfield, Jokl and Suzman (see below). One would not for a moment try to defend the poor man's carbohydrate diet or maintain that all the criticism levelled against it is unfounded. But one feels that the high working efficiency of the proletariat of the world represents a physiological problem of first rate magnitude. It is proposed to utilise the preliminary experiences, for the arrangement of future investigations with a view to discovering *specific* effects of nutritional adjustments and mal-adjustments: we shall, from group to group and case to case concentrate our attention on such diverse factors as growth, intelligence, physical efficiency and health; the latter factor alone will have to be subdivided in order to enable us to study different aspects, such as resistance power to infectious diseases, accident rate, frequency of absence from work, or mortality. We have reason to believe that only such an approach to nutritional research will enable us to collect information of a kind that will make practical dietary and other measures on an effective scale possible.

A STUDY OF THE EFFECTS OF VITAMIN C UPON PHYSICAL EFFICIENCY.

In this section we report on an eperiment in which exact information was sought on the effects of a well-known and much studied dietary factor: Vitamin C. The physiological and pathological significance of this vitamin is exactly known and many statements, unsupported by evidence, have been made to the effect that an "insufficient" supply of Vitamin C would adversely affect physical efficiency. However, no convincing evidence was presented as to the amounts of Vitamin C required by physically active individuals, workers and athletes. This part of our study was undertaken after a survey of the literature on the effects of Vitamin C upon physical efficiency had revealed an abundance of opinions but a scarcity of relevant experimental facts. We conducted an experiment with native workers employed by a Witwatersrand Gold Mine. Five hundred and seventy-two workers were subjected to the three standard performance tests: putting the shot, sprinting over 100 yards, and one mile running. (In this series the one mile running test instead of the 600 yards test was used since we were dealing with a selected group of physically strong adults). The tests were conducted with two groups of native workers. The one received additional supplies of Vitamin C in their diet, while the other group was tested for purpose of control. The tests were repeated at different stages of the period of observation which lasted seven months.

Our results were entirely negative. The natives who received additional supplies of Vitamin C in no way surpassed the control group which according to widely held opinions would have to be regarded as showing a deficiency of Vitamin C. To many, our results may appear surprising. It has often been stated that physical exertion and exercise lead to an increase of Vitamin C requirements (Harmel, Ratsinamanga, Gaehtgens, Borgmann, Schroeder). None of the above authors has presented measurements of physical efficiency. Harmel publishes results of chemical tests in connection with exercise and sport. He, as well as Jezler and Kapp, note a decline in the excretion of indophenol reducing substances after exertion. There is no evidence available as to whether this decline must be interpreted as indicating a decrease of physical efficiency. However, this very conclusion has been drawn by many authors. Our results do not support such a view. Mensching (Rietschel and Mensching, 1938) described a self-experiment in which he lived on a practically Vitamin C free diet for a hundred days. Although during this time his plasma ascorbic acid fell from 0·72 to a value that he was unable to measure, his physical efficiency remained unimpaired, and he continued to take part in military exercises.

The significance of the negative result obtained in our experiment can only be grasped if further evidence is presented showing the potentiality of the method employed. Whilst factors such as age, weight, race, sex, puberty and economic environment yielded significant differences in our tests, the same methods failed to demonstrate even the slightest differences between the Vitamin C group and the controls.

DEFICIENCIES AND EFFICIENCY.

In the course of this survey, it has also been possible to make certain clinical observations which throw new light on some aspects of the problems of physical efficiency. Experiences with athletes and gymnasts have demonstrated that many, if not most, of the existing concepts of the relationship between health, fitness and physical efficiency are fundamentally wrong. We have on previous occasions been able to present a considerable number of clinical case histories of athletes afflicted with pathological conditions of various kinds: e.g. the case of a man who became a successful skiing champion after amputation of one leg; that of an outstanding swimmer with general paralysis of the insane; of a well-known physical training instructress with advanced myasthenia gravis; of several patients suffering from single or combined valvular defects of the heart who gained fame in various branches of athletics; of boxers with severe traumatic encephalopathy winning their fights (Jokl). While conducting these physical efficiency tests, several cases of a similar kind were encountered. In Durban, four Indian children belonging to the same family who suffered from an advanced state of osteopathy of the legs, probably of syphilitic origin, who showed good athletic performances, were studied. A coloured boy of 15 years of age was seen, who while leading in a 600 yards race by about 25 yards, became victim of a typical petit mal. The attack lasted about three to four seconds whereafter he regained control over his movements and managed to pass the finishing line as winner. As he afterwards suffered from combined retrograde and anterograde amnesia, he was then unaware of his success as well as of the epileptiform attack which had preceded it. Several children taking part in the tests showed permanent sequelae of diseases of the central nervous system; we especially noticed many old cases of infantile paralysis with paresis and partial paralysis, as well as spastically paretic conditions due to Little's disease. Some of these children were so handicapped that they were not able to take part in test races; but in several instances of less disabled children one was struck by their athletic zeal and by the fact that their actual performances were better than those of a certain section of the "healthy" children.

As against the above kind of experiences, a large group of children who although "healthy" from the point of view of the examining physician, were found to be much below par in the physical efficiency tests. This group included a variety of types. Firstly one found that it is the over-fed child, the " fatty ", who is incapable of carrying out with reasonable efficiency performances like sprinting or long distance running. Secondly, there are children who have a deeply rooted dislike of physical activities although it can often be shown in such cases that their physical capabilities are actually good. There are others who tire out more easily than the average without any abnormalities being present to explain this deficiency. The physiological decline of endurance and speed in women during and after puberty has already been mentioned.

Thirdly, there is a group of healthy children who proved to be outstanding in their performances. This in itself should be expected if one examines large numbers. However, an endeavour was made to discover characteristic features in such athletic individuals. For example, one found that children with protruding cheek bones were often conspicuously outstanding in endurance power; that heavy body weight is always a handicap to running over extended distances, while thin and " wiry " children show a special aptitude for long distance running. On the other hand, the " heavy weights " were bound to come on top in the shot putt event. Poor boys, as a rule, were at least equal in their endurance power to those who are economically more fortunate; the same statement cannot be made with regard to girls.

Many further observations have been made pointing to the existence of determining characteristics of physical fitness, skill and endurance. It is intended to follow up in further studies some of the clues given in the course of this survey.

A COMPARATIVE STUDY OF THE DISTRIBUTION OF SCATTER DIAGRAMS CONSTRUCTED FROM PERFORMANCES OF GROUPS OF BOYS AND GIRLS BETWEEN 6 AND 16 YEARS OF AGE (INDIANS).

Several studies have been made by pediatricians and psychologists in which profound changes in the distribution of various physical and mental factors were found in the course of physiological growth. Riedel (1915) and Rischke (1916) demonstrated a marked broadening of the scatter area of the body length between the ages of three months and six years. Thorndike (1914) reported that the distribution of intelligence around the means becomes progressively wider with increasing age.

To our knowledge the problem has never before been considered or investigated from the point of view of physical efficiency. It was, therefore, decided to make a statistical analysis of the performances of one large group of children in order to find out whether similar changes of distribution around the means would be discovered. Although one must admit that the results obtained in this rather extensive study cannot yet be regarded as final, they suggest that very profound changes of a similar kind do take place also with regard to physical efficiency. It appears that with regard to the exhibition of strength the pupils develop between the ages of 6 and 15 years " from a collective species into individuals, good or bad." A narrow and high curve changes into a broad and flat line of distribution. Just the opposite trend of development seems to take place with regard to the sprinting performances, while no significant change of the distribution area is found with regard to the 600 yards running results.

The above findings again tend to prove the correctness of the method employed in this survey, as well as of the theory that physical efficiency cannot be regarded as a complex factor, as is widely believed by superficial observers because of the general use which is made of the term " physical efficiency ". Physiologically we have to give consideration separately to the development of strength, to the development of skill and to the development of endurance. It is intended to continue also the study of the problem introduced in the above paragraph.

FURTHER INVESTIGATIONS.

Further investigations and statistical calculations must be carried out in order to utilise to the full the results of this extensive survey: Firstly, it is intended to conclude the racial survey of physical efficiency. For this purpose we hope to be able to carry out additional performance tests on the following groups:—

(a) Hottentots.
(b) Bushmen.
(c) Coloured community of Rehoboth, S.W.A. (As these Coloureds are racially greatly different from the Cape Coloureds who have already been tested, a comparison should be valuable).
(d) Hereros, S.W.A.

Secondly, an attempt will be made to obtain conclusive evidence with regard to the question of the influence of economic environment and of nutritional background upon physical efficiency of European children. For this question, comparative investigations on large groups of children are planned. European children living on different economic levels with closely similar representation in the various age groups will be examined and the results statistically evaluated.

Thirdly, an attempt will be made to examine groups of children whose diet is known to be different with regard to certain factors or combinations of factors. It will then be discovered whether and in what way such deficiencies are of practical significance.

PART II: THE STANDARD OF PHYSICAL EFFICIENCY IN SOUTH AFRICA.

In this second part of our paper, we have to make the statement that the standard of physical efficiency in South Africa is low. We realise the significance of this statement and we are also aware of the difficulty of proving it. Primarily we base our contentions on many years of practical experience in this country—of school children of various races; of competitive athletes, players and gymnasts; of students of the larger South African Universities and Colleges, such as Stellenbosch and Witwatersrand; and also of pupils of the non-European schools and University Colleges at Healdtown, Lovedale and Fort Hare.

There can be, no doubt, that an impressive discrepancy exists in this country between the national efficiency potential and the actual standard of performance of the population. We recently tested groups of European school children in this country according to the well elaborated physical performance standards for school children of a continental country where physical training is highly advanced. We found that the South African children were quite unable to cope with the requirements of these tables, especially in all those activities which require the display of skill. The groups of children tested came from schools where physical training had already been introduced. But we must point out that the time devoted to physical training in these schools, as is at present also the case in practically all other South African schools, is totally inadequate. In a Johannesburg High School for Girls, we found that less than half of the pupils of the 10 to 15 years of age groups were capable of running a distance of 600 yards. Because of wide-spread ignorance on the part of teachers and pupils, as well as because of lack of discipline, many of the older girls do not take part in any physical training at all for almost half the month, imagining that they are unable to do so because of menstruation. In the case of the boys, we find that the attitude towards physical training and consequently their standard of physical efficiency depends on their general educational level. The better the school the greater their physical efficiency. This was particularly striking among the natives. The uneducated native becomes what we would call in every day language "utterly lazy" as soon as puberty sets in. This applies to boys and girls, although to the latter more strikingly. In the few modern native schools, such as Healdtown where investigations were carried out we found a much more favourable response to our attempts to introduce modern physical training than, for example, in rural districts in the Transkei.

There was scarcely any difference in physical efficiency between physically trained and untrained groups in the case of small children. In fact, we were impressed with the keenness and with the high standard of working capacity of untrained young Bantu, Indian, Coloured, and particularly of poor European children whom we tested. It is known, especially from Schlesinger's studies, that the differences in physical efficiency between trained and untrained individuals increase with age. This observation we have fully corroborated in the course of our investigations. Such experiences naturally invite certain practical conclusions which will be made later.

In European schools particularly one finds a few pupils who are keen on games and who represent their schools in competitions with other schools. It is often forgotten that this system affords opportunities of training only to a very small percentage of the total number of children and that, therefore, this system is entirely unsatisfactory from the educational, as well as from the Public Health point of view It must be emphasised that it is particularly the type of child who does not spontaneously take part in physical training that is most in need of it.

It has already been remarked that a discrepancy exists between the efficiency potential and the actual performances of the South African young population. This is borne out by many years of experience of practical instruction and supervision of physical training. It is remarkable how rapidly those few South African youths, who have undergone systematic courses of physical training, have improved their performances. The rapid improvement of physical fitness of the Stellenbosch students after introduction of physical training in 1936 was a most impressive experience. The sudden rise of athletic efficiency of the Witwatersrand University team, in 1933, after the—unfortunately temporary—introduction of systematic coaching classes, was most striking. The outstanding successes of the small group of South African teacher students who during the last few years went overseas to study physical education, represent convincing proof of our assumption that the physical efficiency potential of our youth is very high. The limited data so far available in this country with regard to the physical educability of the Bantu are most promising. In the light of the outstandingly high standard of physical prowess of Negro athletes in the United States of America, it would appear that in the labour potential of our Bantu population we have another deposit of gold in South Africa, a deposit which has not yet been tapped, but which in contrast to the Witwatersrand Gold Reef will prove inexhaustible.

The few highly qualified experts on physical training who have come from overseas to South Africa agree as to the high learning power of South African youth. In 1939 Mr. Bukh's famous Danish gymnastic team visited this country. Fortunately it was possible to obtain the services of a few members of this team, who remained behind as teachers. At least two of the institutions to which these Danish instructors were allotted, were able within a few months, to present displays of the same type of exercise which the Danish students had carried out, this time by South African students. The standard of these displays was scarcely different from that shown by their Danish masters.

That in spite of the absence of sufficiently organised and scientifically planned physical education in South Africa, our representative teams have not infrequently achieved successes in international competitions against competitors coming from countries in which physical training is based on many years of educational tradition is further proof of our theory that the labour potential of South Africa is very high. The numerous practical conclusions to be drawn from our observations as set out in this chapter, will be discussed in the last part of this paper.

PART III: THE EFFECT OF TRAINING.

We shall next present some of the results of a training experiment on young South African recruits which was conducted over a period of more than six months by C. Goedvolk and E. Jokl. Parts of this study were presented by Jokl at the 1937 Annual Meeting of our Association at Windhoek.

From our own figures as well as from other data, it can be seen to what extent the working capacity of young individuals can be raised through physical education. Our own data have been obtained from a series of investigations carried out in a group of 32 South African boys between 16 and 21 years of age. The object of this study was to determine the effects of a short course of systematic physical exercise on young men, who almost without exception were drawn from country districts. Most of them came from poor farm families, and although it would be unjustified to call them destitutes, the environmental conditions and especially their education had been greatly neglected. Virtually all of them arrived in a poor nutritional state. The investigations carried out before commencement and later on in six weekly intervals during their Special Service Battalion training at Roberts Heights, aimed at determining the following measurements:—

1. Weight.
2. Anthropometric measurements.
3. Pulse rate (during rest and after standard effort).
4. Vital capacity (during rest and after standard effort).
5. Breath holding time.
6. Blood count.
7. Muscular tone.
8. Athletic performances.

We must confess that we did not anticipate striking results. The human material at our disposal in this experiment was certainly not representative of the best physical type of South African youth. The period of training (six months) was short. The experimental persons had already passed the phase of formative growth and were changing from the age of physical plasticity into that of adult rigidity. We are at the present moment engaged in an attempt to translate the physiological improvement achieved during the short period of training into terms of economic earning power. We only wish to say here that the increase in material efficiency thus established is considerable.

RESULTS: (Preliminary Report). The training had a profound effect on the efficiency of the recruits. Almost immediately after the commencement of camp life the weight of the young men increased. The gain which amounted on the average to 10 lbs., was almost entirely due to muscular development. This can be concluded from the results of the anthropometric measurements such as those of the circumferences of arms and legs; from the examination of the tone of the muscles; from the photographic posture studies; and lastly from the considerable increase in strength which was demonstrated by the results of athletic tests. In other words, the strength of the boys underwent a sudden improvement, showing that the education of their muscular efficiency had been grossly neglected in the preceding years.

What about their endurance? The performances in the three miles running test showed a constant improvement during training. This improvement is not only expressed in the decrease of their actual running times; the number of recruits who were able to finish the race became increasingly larger with the length of training period. This result alone indicates a functional adjustment of blood circulation and respiration. The extent of this adjustment is demonstrated by the decrease of the resting pulse rate as brought about by the exercise. While before training the average pulse rate during rest was 78 per minute, it dropped after six weeks of training to below 60. We have ample evidence to the effect that a lowering of the resting pulse rate during training can be interpreted as an expression of an improvement of the endurance power of the circulatory system. Still more striking are the results of our investigations of the ability of the recruits to hold their breath. The young men, before the commencement of the training period, were only capable of holding their breath for 38 seconds. This time is indicative of a very poor state of respiratory efficiency. Schneider considers 45 seconds as the lower limit of the norm in young people. During training the breath-holding time increased to an average of about 70, several boys being able to hold their breath for two minutes. It is agreed that a breath-holding time of 65 seconds is very satisfactory for young people, and a time of 70 seconds is usually regarded as sufficient to pass an air force medical test. In the light of these facts, the effect of the physical training upon the respiratory efficiency of the young men is impressive. The training developed them from a sub-standard level to a level of efficiency which is clearly above the average.

That the skill of the trainees had undergone a profound improvement during training is beyond doubt. The 100 yards running times showed an improvement of more than one second. The aptitude of the recruits for military and industrial tasks had increased to such an extent that the majority of them were absorbed into industry after conclusion of the six months course, while prior to the course they had found it impossible to obtain employment. Their general bearing and their discipline, both of which were rather unsatisfactory when they arrived at camp, were very good, and it is no exaggeration to state that their entire personality had undergone a profound change for the better by the end of their training course.

This investigation on Special Service Battalion recruits has been presented in some detail merely because it is, to our knowledge, the only available scientific study of the effects of training on South African youths. The extent to which scientific physical education can develop the standard of performances is much greater than is indicated by the results achieved in our S.S.B. survey. This assumption is borne out not only by the numerous casual observations of the effects of physical training on various functions (see the monographic descriptions by Loewy, by Herxheimer and by Steinhaus) but also by our own observations on young South Africans in primary and high schools as well as in universities. If physical training is applied to the socially superior type of youth found in these institutions, the results are bound to be more striking than if applied to less plastic human material.

We have come to the conclusion that the standard of physical efficiency in this country is unsatisfactory. This is proved by a comparison of the performance levels of our young people with those found in other countries where physical training is treated with more consideration. On the other hand, we have reason to state that the efficiency potential of various South African groups is exceedingly strong. In fact we are under the impression that at least with regard to Europeans and Bantu, it is extraordinarily high. But we are satisfied that unless a lead is given by the State the present unsatisfactory conditions will persist. We wish, therefore, to put forward the following suggestions:—

The existing skeleton organisation of the National Advisory Council of Physical Education, as founded in 1937 by the Government, should be reorganised so that it can be used to introduce within a specified period, not exceeding three years, and to supervise efficiently the following scheme.

1. Introduction of one daily period of physical education for every child. This must under no circumstances add to the total number of teaching periods. In other words it will be necessary to reduce the number of scholastic classes.

2. The elaboration, without delay, of special educational methods to develop the physical working power of non-European groups throughout the country.

3. The introduction of well specified performance standards which must be reached by children of various age groups before passing them from a lower to a higher school standard.

This scheme will necessitate many additional measures of which probably the most important will be that of adjusting existing nutritional deficiencies. Enough information is now available with regard to this problem in South Africa to allow of an adjustment within a short time. The training of physical education teachers will have to be thoroughly organised. Instead of large numbers of teachers' courses, most of which are at present of a low quality, it will be necessary to concentrate on the further development of three central physical training teachers' institutions only: One for Afrikaans speaking students in Stellenbosch, a second for English speaking students in the North, and a third for the requirements of the non-European population, probably at Fort Hare. Since without first class physical training teachers the entire scheme is bound to fail, and since at present many of the physical training teachers' courses in South Africa are of an unsatisfactory kind, it is urged that in future the Government subsidises the above three schools only, which would thus be able to engage staffs of experts without which a first class course cannot be organised. At the same time expenditure will have to be sanctioned for the preparation of playing fields, gymnasia, swimming pools and gymnastic equipment.

PART IV: THE ECONOMIC VALUE OF PHYSICAL EDUCATION.

According to G. D. H. Cole "it matters greatly to the economist that he should be equipped with the best possible statistics about the actual happenings in the economic world." However, one of the most fundamental of the "actual happenings" in the economic world, namely, the capacity for physical labour of the workers, has not yet been statistically assessed. We believe that the results of our survey will, for the first time, enable us to give an exact account of this problem. Adam Smith, the great British Economist, was the first to state that labour is the primary source of wealth. Since its first pronouncement, this statement has never been challenged. However, surprisingly few earnest attempts have been made to draw from this economic theory the necessary practical conclusions. Cole makes the important additional statement to Adam Smith's thesis that labour, in order to be a source of wealth, must be "directed to some foreseen end." In other words, it is labour plus an intelligent plan that is required for producing wealth. We thus have, first of all, good reason to demand that the labour capacity of the population should be developed to the highest possible level of efficiency. Once this aim is realised, we are capable of estimating quantitatively the working force at our disposal in the country. We shall then have little difficulty in proceeding with the second part of our task, that of elaborating intelligent plans to lead the powerful stream of labour into well defined channels of production.

It is not intended to discuss in this paper the figures obtained from our survey to indicate the increase of the earning potential in this country which will be available once physical education is added to the syllabus of scholastic and general education. We are at present still occupied with the calculation of these figures, but can already state that the increase is considerable. The total labour force which could thus be mobilised through modern education would be formidable. The number of schemes of work of national importance to be tackled on a large scale is very great indeed; there are agricultural and industrial tasks; road building and irrigation; liberation of large stretches of our land from malaria and other pests; slum clearance and reclamation works, as well as other plans which could thus be put into practice. Since the hitherto unknown, and, therefore, unexploited factor human labour can now be assessed and budgeted, it will be possible to make use of it for the production of wealth; we shall be able to state the amounts required to be invested, and to foretell the returns which may be expected. There are many human problems which will find a solution in such schemes. In the course of our studies we were impressed with the helplessness of large groups of the South African population and their inability to come to a solution of their profound difficulties. The question of rehabilitation of poor Europeans; that of firm guidance of the South African Bantu, to enable them to produce the necessary material values to maintain themselves in and adjust themselves to conditions of modern life. The problem of what is now called the "penetration into European areas" of Indians; and last but not least the pathetic situation in which the coloured people of South Africa find themselves to-day. What has impressed us most in connection with all these and other problems, was on the one hand the almost entire absence of intelligent planning to tackle these problems, and on the other hand the slight extent to which the working power of those people is being utilised. Such a state of affairs is surely not in the interest of the community. If a considerable number of people are unemployed, or if their working capacity is not fully utilised, their earning power is reduced or even non-existent. This state cannot be improved by subsidies or other means derived from taxing the rest of the community. No increase in total purchasing power can thus be achieved. Only planned development as well as scientific organisation of human labour can in reality lead to an increased production of wealth. "That community has the highest real income," Cole writes, "which makes the fullest and most productive use of all its economic resources. It cannot pay a community to keep some of its citizens in idleness when they could be employed in the production of useful things."

One of the few medical men who have made a study of economics, Walter E. Elliot, has often stressed the second aspect of the problem with which we are dealing in this part of our paper, that of integrating labour and production in a planned scheme. In his rectorial address delivered at Aberdeen University in 1934, he emphasised the essential role which organisation has to play in labour and industry "if we are to meet the uneasiness and insecurity of the present day." Of his practical suggestions that to "organise smaller units and gear them up to each other" is the one with which we shall have to make a start in this country. In other words, we feel that what is needed to ameliorate the plight and poverty of the underprivileged groups of our South African population is not only the profession of "liberalism," but also, and the importance of this cannot be too greatly stressed, intelligent action.

We believe that physical education has a true function in education only if by its means we improve the standard of health and physical efficiency of our population for a definite purpose In normal times this purpose will be mainly the production of a labour force to produce wealth and health, and from that contentment, security and happiness. In times like the present where the most fundamental issues of our lives are at stake, a high labour potential of the population will strongly contribute to our military strength. In other words, physical education leading to a permanent state of mobilisation of the labour capacity of the country must also be regarded as pre-military training. No country can afford to neglect this aspect of education as has so dramatically been exemplified in the tragic fate which has recently befallen France. The average individual cannot be expected to understand the significance of the social problem involved. Whether the question is viewed from the educational, from the economic or from the military aspect, it is equally in the interest of the State that every individual reaches the highest possible standard of working power and health. The attainment of clearly defined standards of physical efficiency must in future be demanded in the same way as we to-day demand from every European citizen of the country the attainment of certain minimum standards of intellectual development.

We are aware that some of the conclusions which we have drawn from the results of our experimental survey imply interference with what may be regarded by some people as "personal freedom". However, that interference with personal freedom which we recommend, that element of compulsion which we feel our duty to demand, appears to us a fundamental necessity in the interest of the community as a whole, and of the individuals constituting that community. We clearly foresee that "reasonable compulsion" will in the society of the future have to be introduced, unless the society is prepared to give up its free existence. In the past the unwillingness of the intellectual classes, of the representatives of science and of learning, to consider compulsion has been one of the most profound mistakes which in their effects have proved to be catastrophic; as catastrophic as the adoption of the principle of compulsion without reason which we have recently seen introduced in so many parts of the world.

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THE COMPOSITE CHARACTER OF PERSONALITY

BY

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ABSTRACT.

This theory has been raised upon the correspondence that exists throughout the organic realm, from the cell cycle of the lowest forms of life, the unicellular organisms, to the life cycle of the human organism. The three phases, gregarine, infusorian and rhizopod, the very passive, the very active and the midway amoeboid phase, are fundamental expressions of life.

The following diagram shows the seven biological levels of the human organism, as they have emerged in the evolutionary process. The first phase, the passive vegetal factor, characterized by introversion, is represented by levels 1, 2 and 3. The second phase, the subcortical sthenic factor, is marked by extreme activity and extroversion, at levels 4 and 5. The third phase, the cortical deliberative factor, at levels 6 and 7, is characterized by activity of a measured nature: the value is partly subjective, partly objective.

But these three divisions were inadequate. They offered no explanation for the fact that a dog or a rat, could live after the removal of the cortex: there was no explanation for the "mixed states" such as excited depression and manic stupor: nor for the extreme difficulty experienced by Psychiatrists in making a diagnosis of manic-depressive or schizophrenia. The solution was provided by the red locust, with its three phases, the egg, the hopper and the flying locust. When a hopper swarm on the move is disturbed, the measured movement is immediately changed to activity of an undeniably sthenic character. The conclusion was inevitable, that each major phase is similarly cyclic, exhibiting the three characteristic phases, but in a minor key. Thus at the vegetal level, sleep may manifest as coma, light sleep or nightmare, corresponding to levels 1, 2 and 3.

The seven stages, ontogenetic and phylogenetic, in the evolution of the whole man. The three major "factors" are analogous to the three phases in the cell cycle of the unicellular organism: each major phase is similarly cyclic, exhibiting the three characteristic phases but in a minor key.

Cortical Deliberative Factor.	C	Moral factor.	7	frontal lobe.	Freud's Super-ego.
		Pure Reasoning factor.	6	Cortex excluding Frontal lobe.	Freud's Ego. Jung's Introvert. Rivers' Epicritic sensibility. Spearman's g factor.
Sub-Sthenic Cortical Factor.		Affective Sthenic	5	Neo-thalamus.	Freud's Id. Jung's Extrovert. Rivers' Protopathic sensibility. Spearman's S factor.
	B	Pure Sthenic	4	Cerebellum and palaeo-thalamus.	
Passive Vegetal Factor.			3	The system of preganglionic and postganglionic sympathetic neurons through which the central nervous system curbs and controls the visceral activities either directly or through 2.	
	A		2	Peripheral autonomous nervous system.	
			1	Local non-nervous tone and specificity of the organs and their control through endocrines.	

The question arises as to how the functioning at various levels is co-ordinated to ensure organic unity. The answer is to be found in a central Psyche or Pure Ego, which although a composite of the various levels, is not itself a mental event, nor of the nature of the events which it unifies. The proofs for the existence of such a Pure Ego are many: it must suffice to mention that a subject in hypnosis will react to an improper suggestion by waking up: Freud likewise was constrained to postulate a "Censor", an entity distinct from his ego, id and super-ego.

When the theory had reached this stage, it became evident that the cortical and subcortical factors, were comparable to similar associated pairs in the theories of Freud (ego and id), Jung (introversion and extroversion), Rivers (epicritic and protopathic sensibility), and Spearman (g and s factors).

It may be objected that the association of subcortical functioning with extroversion implies mental deficiency in the extrovert. To remove this misconception a picture of the introvert-extrovert relation is necessary. The cortical thalamic and subcortical levels represent the cognitive, affective and conative aspects of mental process: but there is a special affinity between the cognitive on the one hand, and the affective and conative aspects, which is comparable to chemical affinity. This manifests itself by an irrational, uncritical acceptance by the factors at 4 and 5 of all propositions from the factors at 6 and 7. A glimpse of the mechanism is afforded by the phenomena of schizophrenic negativism, where the affinity is disrupted, and cortical and subcortical factors function independently. The introvert-extrovert relation may best be expressed by the formula ($x+y=100$), where x represents the cortical and y the subcortical factor: when x is greater than 50 the subject is introverted, when y is greater than 50 the subject is extroverted: only when $y=100$ is there dissociation of the cortex, as in hysteria and mania.

The claim is made for this theory that it explains the facts of behaviour better than other theories, and that it offers man the power and the inclination to adapt his social system to a changing environment.

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RECORDS IN THE SPECIAL CLASS.

BY

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One of the problems associated with special or deviate classes in primary schools is the keeping of records. The methods used in ordinary classes are not well adapted for use in special classes for two main reasons, namely, that special classes differ very greatly in composition from ordinary classes; and that special teaching methods based on intelligence and scholastic tests have to be used.

This paper describes a system of record keeping which was designed and developed after much thought and experiment to meet the requirements of the special classes. It is in successful operation in the special class at Mowbray School, Cape Province. An ordinary school class is comparatively homogeneous in composition but a special or deviate class is a discrete collection of individuals differing widely in ability and standard of attainment with a possible range in ages from nine to sixteen years. The personal details of each pupil in the class should include information regarding the child's family, intellectual ability and character to a more detailed extent than is necessary in ordinary school work. Some of the information is of a highly confidential nature and must at all times be treated as such. The relevant documents may be voluminous but must be kept in an easily accessible form. The progress records of each child must likewise be kept in a readily available fashion. These records are a collection of individual records, as compared with the general class records of an ordinary class. It is, however, very essential that a class spirit should be fostered and developed so as not to allow the children to regard themselves as different from the rest of the school.

The system designed consists of a fold-over card, 9½″ x 8″, and accompanying folders, for each pupil. The cards are best kept in a visible edge index unit, and arranged alphabetically. On the card are recorded personal particulars and progress in school work, as shown in the accompanying forms. A space is provided for photographs taken on admission, on leaving and at some intermediate time. These may be taken with an ordinary box camera and should show more of the subject than a pass-port photo. A small portrait lens attachment is an advantage. In addition to the information on this card each child has folders devoted to work, personal case history and any other details necessary. These folders are filed numerically in a drawer cabinet, the reference numbers being given on the visible edge of the index card.

The order of the folders does not necessarily correspond with that of the index cards There are no blank folders, only as many being in use as are required from time to time. If a visible index unit is used the visible edges of the cards show sex, name, age to the nearest half-year and file references for each member of the class. Such a unit should be kept in a locked cupboard when not in use.

In addition to the personal index cards described above and illustrated, other index cards and folders are used to record and keep information and papers important to the class as a whole. The records to be kept vary with individual classes. Separate cards and folders may be devoted to:

a. Correspondence (Name, Address, Reference).
b. Class Activities.
c. School Activities.
d. Clinics (Medical, Dental, Child Guidance).
e. Inspections (Special Class, General, Medical).
f. Past Pupils (Name, Address, Occupation, Class, Year).
g. Education Students (Name, Institution, Date, Work).
h. Class Expenses.
i. Scholastic and Diagnostic Tests.

The general method of using them is similar to that described for the personal records; condensed information is given on the cards, and other documents such as correspondence, accounts and reports are kept in the folders, the reference members being given on the corresponding index cards.

It should be recognised that the system consists essentially of the index cards and accompanying folders or files to which reference is made on the cards. If visible edge units and fire-proof steel filing cabinets can be afforded they should certainly be used, but it must be stressed that the furniture for storing the records, though necessary, is not restricted to any one type of equipment. If expense must be curtailed plain wooden boxes may be used for the files and a smaller box for the index cards. Such boxes would have to be stored in a cupboard or drawer which could be locked. Working on these lines the cost of cards and folders for a class of 20 need not exceed ten shillings, assuming that the system is used by a number of classes to make it worth while having the cards printed.

It is generally considered that a filing system is expensive and the system is often confused with the cabinet and other requisite equipment. To show that a system need not necessarily be expensive the approximate cost is given of cards and folders for a class of 20 viz., 20 printed cards, 10 plain cards, 20 personal record folders, 20 work folders, 8 general folders.

	s.	d.
20 cards printed at 100/- a 1,000	2	0
10 plain cards at 33/4 at 1,000		4
4 doz. folders at 12/6 a gross	4	2
	6s.	6d.

The costs given for the separate items may increase owing to war conditions but the figure of 10/- (ten shillings), including a small amount for wooden or cardboard boxes, should be adequate.

Experience of the system described in this paper has proved it to be convenient and efficient in use and a great aid in the general working of the class. The system could be used, with slight modifications, for any type of special or deviate class or for industrial or special schools.

Name of Pupil Special Class

Date of Birth		Date Admitted	
Place of Birth			
Father		Occupation	
Mother		Occupation	
Living with			
Addresses			
1	2	3	4
Previous Schools			
1	2	3	4
Family			
Home Visited			
Left Class		Reason	

PHOTOGRAPHS

Date	1	2	3
Age			

Fig. 1. (Actual Size 8″ x 4 9/16th″). Folded over part of the card which is seen first. The information given here is supplemented by the records kept in the personal folder. The photographs are attached to the card by means of transparent fixing corners. Each photograph is numbered and dated.

I.Q. Tested by: Date:

	1940	1941	1942	1943	1944	1945
Reading Age						
Spelling Age						
Arithmetic Age						
Educational Age						
Competition						
Spoken Language						
Second Language						
Handwork						
Musical Apprec.						
History & Geog.						
Sports & Games						
Height						
Weight						

Sight	Abbr. S=Satisfactory
Hearing	U=Unsatisfactory
Speech	
Handedness	
	Note: Ages according to Burt
	Scholastic Tests

GENERAL CHARACTERISTICS

Personal Appearance

Habits

Industry

Trustworthiness—Work

Trustworthiness—General

Social Qualities

Leisure Occupations

Special Talents

Home Environment

M	F	Name	Age	8	9	10	11	12	Ref.
				13	14	15	16	17	

Fig. 2. (Actual Size 9⅜" x 8"). Inside of the card seen when the folded part is turned up. The information entered here shows the attainments and progress of the pupil from year to year. The exercises, examination papers and other relevant papers are kept in the work folder. The last line on this side of the card is visible if the cards are kept in a visible edge container. The age is shown to the nearest half-year by marking the age spaces in colour. For convenience in typing the name, etc., the blank card extends below the last line shown in the Figure. After typing this part is cut or torn off along a perforated line

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EVENING DISCOURSE

SCIENCE AND SOCIETY

BY

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Read 2 July, 1940.

INTRODUCTION.

The advent of a second world war, a war in which all the potential forces of Science which may be applied to the annihilation of Man and of the Society which he has created, have been unleashed to further the aims of destruction, a war in which victory is to a large extent conditioned by ownership of the swiftest planes, the stronger tanks, the most efficient bombs and shells;—the advent of this war with machines of destruction which threaten the very existence of their creators, has caused many people—scientists and laymen—furiously to think. We have sown the dragon's teeth. Can we escape the armies which have sprung from them? Can science, which appears to be getting out of hand, still be tamed to the service of man and not to his destruction, or must we go from catastrophe to catastrophe until Science, the tool of Society, becomes its master and, under control no longer, destroys that which created it?

Such reflections as these must lead the thinking man to a reconsideration of the fundamentals both of Society and of Science. In their essential nature, both the coming together of individuals to form corporate societies and the unremitting endeavours of investigators throughout the ages to build up an increasing sum of human knowledge, appear as most desirable human activities. And yet with all our institutions and all our knowledge we live in the continual shadow of fear. Is the fault with Science, with Society, or with both? Before we can answer these questions we must study the history of Society and of Science; we must endeavour to determine in what ways each has conditioned the other, we must look for the obstacles, natural or artificial, which have prevented the synthesis of Society and Science into an harmonious unity of progressive forces.

HISTORIES OF SOCIETY AND SCIENCE INTERRELATED.

It is customary to class the last 150 years or so as the "Age of Science." Science is however almost co-extensive with Society. As soon as the first primitive unit of Society, the family of husband and wife and children, found that its security could only be achieved by a union with other similar units in order to build up a strong clan or tribe, so soon did the necessity for Science appear. With the game on which the hunter fed becoming more dispersed and timorous, hunting demanded new skill and fresh implements. Technicians, whose duty it was to ensure a steady supply of the tools of hunting, became a specialised brand of Society, the first skilled craftsmen, the first scientists. As an agrarian economy followed and slowly displaced the primitive hunting economy the need for specialists increased. The most propitious times for sowing and reaping, the rainy and dry seasons, the phases of the moon; later, the rotation of the crops, the prevention of plant diseases, the best methods of storage, etc., all claimed the closest attention of the community because its continued existence obviously demanded that it should control natural forces to the best of its ability. The priests became a scientific hierarchy in the tribe. They became the real rulers exercising a benevolent despotism which guaranteed the welfare of the community. (Some of us think that a similar scientific despotism might not be too bad a thing to-day) Answering the demands of the agriculturist, Science made really astonishing progress. Astronomy, in particular. advanced by leaps and bounds. Stonehenge, the pyramids and other megalithic monuments remain as memorials of scientific achievement in an age when accuracy was secured by having the apparatus as large as possible. The Great Pyramid is recognised to-day as an outstanding feat of architecture and scientific exactitude. It was not intended by its builders to foretell Armageddon or the restoration of Israel. Its object was much more direct and practical. The Egyptian year was based on the heliacal rising of Sirius, the brightest star in the sky. Some time in what we now call July it would appear on the eastern horizon a few minutes before sunrise. This was the dramatic moment, for it announced the beginning of the year and the flooding of the sacred Nile which brought prosperity to the cultivators. Sirius thus became Egypt's timekeeper. Now at its transit across the meridian. the rays of Sirius were at right angles to the South Face of the great Pyramid and shone straight down the ventilating shaft into the royal chamber illuminating the head of the dead Pharaoh.

Agriculture demanded times and seasons, the demand was answered by the priests, the scientists of those days, the founders of astronomy. Here we see the close interrelation of Science and Society, how the investigation of natural phenomena and processes is conditioned by the presence of a practical demand for knowledge necessary to life. We shall find many other instances where Science is so conditioned by Society. The study of astronomy, however, did not content itself with the ability to correlate the changes of nature and the periods of the celestial bodies. Incidental to the main theme of study, a whole host of natural rhythms not directly associated with the fertility of the earth were discovered. Here might be claimed the emergence of "pure" science as contrasted with " applied " science. It is interesting to note, however, that even pure science soon found its practical applications. Thus the early acquired ability to predict eclipses although it had no social value as regards the nurture of the people, soon became in the hands of the priesthood who represented these startling phenomena as evidences of the anger of the gods, a singularly effective method, as Hogben puts it, of "increasing the ecclesiastical income tax."

Thus, early in its history we find a dichotomy in the aims of Science—on one hand the concept of Science as a servant of the community with its efforts directed towards increasing the general good—on the other the concept of Science as a source of power enabling one section of the community (not necessarily the scientific) to impose its will on the rest.

We could continue thus through the whole range of social development and show how Science has answered the demands of each form of society as they have arisen. Thus Greek Science, existing in a community largely concerned with the building industry devoted itself to mechanics, devising the lever, the wedge, the pulley, and other pioneer machines. Science decayed in Roman and feudal times with the increase in superstition and oppression, but the rise of the merchant adventurers between the 9th and 15th centuries brought new and urgent demands. Ships and roads were required, world exploration commenced, bringing with it demands for accurate cartography, chronometers, compasses, theodolites, etc., etc. New fabrics demanded new machines and new tools, trade routes had to be protected, Science was finally harnessed to war, and new and terrible implements of destruction were devised. To forward the new science, societies schools and colleges were founded. Kings and princes gave financial support to all sorts of investigations. The age of research had begun. Society saw in Science the promise of a golden age. The omens were propitious. That,' instead, there followed the industrial revolution with all its attendant miseries, then an era of international strife, and wars of conquest where Science was prostituted to the manufacture of high explosives and death-dealing mechanisms, is the tragedy of all time.

THE TWO-FOLD ORIGIN OF SCIENCE.

Modern science derives from two main sources, (I) the observations and ordered reasoning of the magician, priest, or philosopher, and (II) the practical experience of the craftsman. As we have seen these two aspects tended to merge in primitive man who was at one and the same time craftsman and magician. When more complicated ways of life subsequently emerged, a gradual divorce occurred between science and practical life. Science became metaphysics, a gap which was largely unbridgeable was created between the "practical man" and the "philosopher." As a result Science, being divorced from industry, became unreal and uncertain. With the development of modern science this fatal gap has been continually reduced. The Royal Society consisted not only of professional scientists but for the most part of country gentlemen and "men about town." The British Association which was founded in 1831 and which largely superseded the Royal Society became the official popular mouth-piece of Science. Nowadays we are all scientists in that the affairs of science occupy a large part of our thoughts and practice even if our understanding of them may be somewhat imperfect. We talk learnedly of carburettors and calories, electrons and enzymes, valves and vitamins. We more and more apply the discoveries of Science to the ordering of our social activities. We continually demand of science new powers, new means of enlarging our material estate, new weapons against our enemies. We have taken science to ourselves, the wheel has gone full circle, the scientist and the citizen are again one. Society has again assumed control. Science is again its servant, I might almost say, its slave.

Let me give you two examples of how the discoveries of science are not as we so commonly suppose dependent solely on the existence of great investigating minds but are what we may call the "conditioned reflexes" of the scientific world to the demands of an imperious society.

The work of Newton was conditioned by the needs of the Society of his day. There is reason to believe that the most abiding interest of this great mind was the old alchemical puzzle of the transmutation of metals! His sociological background demanded quite different things of him. The telescope had been invented and had found its use in navigational practice. The simple telescope of Kepler, however, consisting of a combination of two lenses, had the serious drawback that all images formed were surrounded by a troublesome pleochroic halo and the greater the magnification the more annoying did this distortion become. Before this fringe could be removed, it was necessary to know much more about the nature of light. To this task Newton set himself. His researches, resulting ultimately in the production of the achromatic lens, are a classic example of the solution of an urgent social problem by the initiation of a piece of "pure" research undertaken specifically for that purpose.

Another necessity of Newton's time was the accurate control of cannon fire. So far cannon had been used more for their moral effect rather than for any material damage likely to arise from their employment. No laws were known whereby the actual range of the shot fired could be determined. Artillery practice was a pure case of "hit or miss." A knowledge of the laws of motion was essential to the successful development of this new implement of destruction. The "Principia" resulted, and in this it was shown that not only the motions of projectiles like cannon balls but also the motions of the Earth and the planets themselves could be expressed with mathematical accuracy. Newton's mechanics were a product of his age. Had there been no Newton there can be no doubt that some other mind or minds, perhaps more slowly and laboriously but none the less surely, would have solved the same problems and formulated the same laws. The times were ripe, the needed scientist appeared. Society had demanded fresh knowledge and the Scientist had answered Society's demands.

As a second example let us take a more modern case. Since we have reverted to the practice of our ancestors and the art of decorating our bodies or parts of them with coloured products, some of the stream of scientific research has been directed towards satisfying these demands. The white-robed, bespectacled chemist you see in the advertisements of cosmetics, intently observing a test tube is not all billy-cock. Clays have to be graded, pigments classified, gums and other adhesives investigated, grinding and grading machinery invented and improved, for the nail varnish must be permanent, the face powder grit-free and the lip-stick kiss-proof. Society makes its demands, Science must satisfy them.

The point, which I trust I have made clear, is that Science is not as commonly supposed a free, unencumbered and disinterested search for knowledge. Its progress, or lack of progress is conditioned at all points by the nature of the Society in which it finds itself. The Scientist is not a man apart. He is a unit in the whole social complex. His work can only find recognition in so far as it conforms to an imposed scale of social values.

THE RESULTING TYPES OF SCIENTIST

How does the Scientist react to these constraints? Science used to be the occupation of curious gentlemen or of ingenious minds supported by wealthy patrons. That is no longer true. Science is now an industry supported by large industrial monopolies or by the State. Has the scientist changed? Essentially no. He still feels the same motivating forces. One of these is psychological. To every true scientist, the exercise of a disciplined curiosity brings an abiding sense of satisfaction. It is this curiosity which recruits scientists. The prospect of satisfying it is the chief motive force impelling the young scientist on his way. It remains with him through life and however overlaid with notions of utility or the service of humanity, it is the factor which more than any other drives him onward.

To this desire to satisfy curiosity must be added the rationalistic motive, the idealism of pure science, the "ding an sich" outlook which regards science without thought of application or reward. This has been lyrically expressed in a passage of T. H. Huxley's—"That which stirs their pulses is the love of knowledge and the joy of discovery of the causes of things sung by the old poet—the supreme delight of extending the realm of law and order even farther towards the unattainable goals of the infinitely great and the infinitely small between which our little race of life is run. In the course of this work, the physical philosopher, sometimes intentionally, much more often unintentionally, lights upon something which proves to be of practical value. Great is the rejoicing of those who are to benefit thereby; and, for the moment, science is the Diana of all the craftsmen. But, even while the cries of jubilation resound and this flotsam and jetsam of the tide of investigation is being turned into the wages of workmen and the wealth of capitalists, the crest of the wave of scientific investigation is far away on its course over the illimitable ocean of the unknown.''

This idealistic outlook on science has much to contend with in these days. All new knowledge is likely to be confronted with the question " Of what use are you " or " How can I use you to increase my wealth, or my comfort or my power over others?" If it can only answer "I do not know" it is damned out of its own mouth.

As a result, more and more scientists are claiming support for their investigations on the ground that they have an essentially sociological bearing. Their idealism is turned to the creation of a better, fuller and easier life for their fellows. The achievements of science are painted in glowing colours, its conquests of various diseases are displayed as the miracles of its power, the increased ease and presumed happiness of at least a section of the population as a result of the extended use of scientific inventions such as the wireless, the cinema and the telephone are instanced as the results of scientific beneficence. Here is how Macaulay regards the science of the Victorian age. " It has lengthened life; it has mitigated pain; it has extinguished diseases; it has increased the fertility of the soil; it has given new securities to the mariner; it has furnished new arms to the warrior; it has spanned great rivers and estuaries with bridges of form unknown to our fathers; it has guided the thunderbolt innocuously from heaven to earth; it has lighted up the night with the splendour of the day; it has extended the range of human vision; it has multiplied the power of human muscles; it has accelerated motion; it has annihilated distance; it has facilitated intercourse, correspondence, all friendly offices, all despatch of business; it has enabled man to descend to the depths of the sea, to soar into the air, to penetrate securely the noxious recesses of the earth, to traverse the land in cars which whirl along without horses, and the ocean in ships which run ten knots an hour against the wind."

Would Macaulay have quite so much to say about the social benefits of science were he writing to-day? What about the reverse side of the medal? What of wars more terrible than ever before, where the accelerated motion of the aeroplane means accelerated destruction, where the mariner is menaced by the submarine and the mine, where the resources of science are harnessed to destruction? What of the general undernourishment of the peoples and the multitudes of unemployed? What of the voluntary destruction of goods which millions need?

And so admiration of the advance of science becomes modified in the severe criticism it draws on itself because of its present day misuse. Some, as a result, turn from science in sheer despair, others, refusing to recognise the social implications of science, find escape from present perplexities by immersing themselves more deeply in the pursuit of their scientific researches. This use of science as a form of "escapism" finds considerable popularity nowadays. To some it has become a kind of religion. The unknowable in science is exalted and the known is ignored. The indeterminancy of quantum mechanics is made an argument for the freedom of the human will. Jeans, Eddington, Whitehead and others have popularised the notion of an *expanding* universe in the contemplation of which the petty worries of our *contracting* earth should become insignificant. Science is divorced from social problems. It is regarded as something pure, exalted, absolute, a philosophy external to man, unconcerned with the daily life and struggles of its votaries. This new non-material science represents a final frustration of all the historical purposes of scientific endeavour, for, as we have seen, science at first originated and has since continued solely as a means of helping man first in his conquest and then in his application of the forces of his natural environment.

THE FRUSTRATION OF SCIENCE.

What, then, is the function of science in society? To what extent has it been fulfilled? As long as science appeared to furnish undiluted benefits to humanity, as long as it increased the wealth and presumably the happiness of the majority of mankind, it was welcomed and the scientist was honoured. Recently, we have begun to doubt, and in the last thirty years or so these doubts have developed in many people into a conviction that all is not well with science. The term "frustration of science" has become a commonplace. Not only the scientist, but the man in the street has come to realise that science is misapplied, that many of the potential benefits of research are never achieved, that the advance of knowledge instead of increasing human welfare and security has in many cases made for suffering and insecurity, that each new discovery is a possible new menace to our very existence, that the control of science has somehow passed into the hands of destructive agencies, and that the initial purpose of science—the betterment of life—is obscured by a shadow of futility. Let me give a few examples. Whilst the British government spends about £400,000 on remedial medical research, it is compelled to spend at least half as much again in the Department of Chemical Research on investigations of poison gas. While preventible diseases like the common cold are largely uncontrolled, while malnutrition is rife, the entire energies of many scientists and engineers must be concentrated on the elaboration of new methods of creating body-destroying machines. While agricultural research—one of the most efficient departments of applied science -continually increases the productivity of the soil, and by the scientific use of fertilisers, the discovery of new and disease-resisting varieties of cereals, and advanced methods of soil conservation, has confounded Malthusian theories which predicted over-population and under-production of the necessities of life, we find that the modern tendency in agriculture is to restrict output so as to maintain prices, to use subsidies whereby uneconomic crops can be grown where nature never intended them to grow, to limit by quotas and marketing boards the natural yield of basic crops, so that, as Sir John Orr points out, one half of the population of Britain has not enough of the right kinds of food to eat. Concurrently with an internal stimulation to research, science is suffering from an external suppression. It is like driving a powerful car with the brakes applied hard all the time. The waste of effort is incalculable. The scientist continues to be tolerated simply because we have not yet become completely irrational. But when he sees his best endeavours frustrated, his inventions "put in the icebox," or applied to such vile ends that had he foreseen their nature he would sooner have destroyed his discoveries rather than add to the afflictions of his fellow-men, is it surprising that the scientist is forced to leave his ivory tower and to condemn such an order of society.

The increase in the number of monopolistic or semi-monopolistic industries is now one of the chief factors restricting research. A monopoly controls and uses immense amounts of capital in its established plants. Research tends to increase efficiency and often does so at an alarming rate. The result often is that a plant laid down at one stage of the development of a process is liable to become out of date within a few years with resulting heavy capital losses. Indeed many plants become obsolete before actual production starts at all. Monopolistic industry by restricting competition, results in the suppression of a large number of new inventions which are as the phrase goes "put in the ice-box." The result is a holding up of technical advance because the *entrepreneur* must be assured a proper return on his outlay. Where monopoly reigns we have a stifling of research and a continued output of old and inefficient designs where newer and more efficient models would be both more economical and more grateful to the consumer.

Thus the ordinary householder is still condemned to the older inefficient filament lamp when there is no reason, other than that of the loss of capital which would be involved were the existing factories scrapped, why he should not use the longer lasting vapour lamps which produce the same illumination with a consumption of about quarter of the current. (The electricity producing corporations are also of course directly interested in this matter.) Again, I understand that a recent invention has made it possible to play straight through a whole Beethoven symphony from a single sound track. The vested interests of gramophone and record companies still condemn one to the continual annoyance of interruption while the record is turned.

Even in the teaching of science we largely frustrate its purpose, and much of the disharmony existing between science and the citizen is due to faulty educational methods. Much High School teaching of science, considered as an introduction to scientific method, is useless. Actually, scientific facts are learned in the most unscientific manner possible. The existing examination system with its emphasis on memorised data which the pupil just must assimilate whether they appear reasonable to him or not, results in a complete negation of any scientific method of approach. The curriculum is generally completely out of date. Few of the discoveries made by science in the last 50 years, X-rays, wireless, radio-activity, the role of accessory food factors, etc., are ever mentioned. Biology is taught mainly as a roundabout method of explaining sexual phenomena. The results of these mechanised methods of teaching are only too evident in the readiness of the average man subsequently to accept as scientific fact anything which appears to have behind it a sufficient weight of authority. Hence the present day widespread belief in spiritualism, astrology and the perverted theories of blood and race which are working such havoc in the minds of their disciples. Hence the dangerous ease of assimilation of anything which is fantastic or mystical, the facility with which fascist demagogues can enslave whole nations.

The purveyor of any new patent food or medicine well knows how easily his victim may be caught by this veneer of pseudo-science. He has but to advertise his product to the accompaniment of a white-coated scientist eagerly examining a test tube and success is his. Anatomical sketches of what the reader's heart, or liver, or colon or other intimate organ may look like, placed alongside an idealised picture of a similar organ in health, persuades him that his only salvation is in "so-and-so's Pills." I am probably not far wrong if I assert that, for the majority, knowledge of anatomical detail is almost entirely derived from advertisements in the public press.

The whole matter may be summed up in the words of Bernal "For those who have once seen it, the frustration of science is a very bitter thing. It shows itself as disease, enforced stupidity, misery, thankless toil, and premature death for the great majority, and an anxious, futile and grasping life for the remainder." So much is this so that voices have been raised even in scientific circles for the suppression, if not of science itself, at least of its applications. The Bishop of Ripon, preaching to the British Association at its 1927 meeting said, "Dare I even suggest, at the risk of being lynched by some of my hearers, that the sum of human happiness outside scientific circles would not necessarily be reduced if for ten years every physical and chemical laboratory were closed and the patient and resourceful energy in them transferred to recovering the lost art of getting on together and finding the formula of making both ends meet in the scale of human life."

SCIENCE AND WAR.

It is particularly in the field of war that this cry for suppression has been deepest, for it is here that the perversion of science has reached its climax. As far back as 1731, John Ozell in his "Persian Letters" quotes from a Persian correspondent "I have not long been in Europe; but I have often heard wise men talk of the Ravages of Chymistry; it seems to be a fierce savage which ruins mankind and destroys them in particular, but continually; while war, plague and famine cut them off in general, but by fits. I often tremble for fear at last some invention will be found out of a shorter way to destroy mankind, and to depopulate nations and whole kingdoms " To which his friend replied " If a fatal invention should be hit upon, it would quickly be forbidden by the Law of Nations, and the unanimous consent of mankind would soon crush such a Discovery." To such a pathetic hope we still cling! Alas, Science becomes co-ordinated in war as never in peace co-ordinated towards destruction, the negation of its primal purpose. In war, we see science unified and directed towards one specific end, the maximum of destruction in the minimum of time. Obsolescence, the bugbear of the manufacturer of civil goods, is of no account in armament production. Apart from the fact that the use of older types of aeroplanes and guns may impede victory or even invite defeat, the munitions manufacturer is only too pleased to substitute the new for the old. It means an increase in his output and after all, it is the taxpayer who will pay for his new plant, while he has also the opportunity of dumping his obsolete weapons on some more backward (?) nation. The idea that the use of novel methods of destruction is somehow unsporting is a relic of the era which we are accustomed to call the " age of chivalry." But warfare, a beastly instrument of national policy can know no limit to its beastliness To the Saracens the use of " Greek fire " was " not cricket " (or whatever they played in those days), the Scottish use of caltrops was an offence against the laws of chivalry, gunpowder introduced murder at a distance for the " honourable " clash of steel. To-day we accept dive bombers, tanks, poison gas as recognised war devices. What to-morrow may have in store, no one knows.

That scientists are not ignorant of the social implications of many of their researches is evidenced by the fact that particularly in France and in Britain many of the most eminent were, before the war, taking an active part in democratic movements aimed at its prevention, and have written many vigorous pleas for the creation of conditions which would make war impossible.

WAR THE RESULT OF AN UNSCIENTIFIC SOCIAL ORDER.

It has become evident to those thinkers that wars cannot be considered either as evils apart or as biological necessities but that they are rather the culminating fevers of a society which suffers from a continual malaise. That there is much grit in the machinery of social progress has long been recognised. The phenomenon of science misapplied was recognised by Swift who in " Gulliver's Travels " wrote " He has been eight years upon a project for extracting sunbeams out of cucumbers" and again "He has it for his opinion, that whoever could make two ears of corn or two blades of grass to grow upon a spot of ground where only one grew before, would deserve better of mankind, and do more essential service to his country, than the whole race of politicians put together." We *have* succeeded in producing more than two ears of corn and two blades of grass for one, and what is the net result. To quote Professor Levy "In 1934, it is estimated that approximately two and a half million people died of starvation and yet in that year over two and a half million tons of wheat, 30,000 tons of meat, 26,000 tons of rice, one-quarter million tons of sugar and nearly three-quarter million tons of coffee were deliberately destroyed in order to raise prices by maintaining artificial scarcity."

This paradoxical situation is a challenge to all thinking scientists. Plenty is secured by scientific effort and yet, because of a system which deliberately curtails the results of this effort, hunger is the continued lot of millions. Are we fighting a losing battle? Are all our best efforts at human betterment to be frustrated? Take the case of dietetics. Science has investigated and now knows exactly the food factors essential to human health especially those "accessory" factors known as the vitamins. It has recorded their natural occurrences, it has observed the diseases which arise from their lack or deficiency, it has synthesised many of them. And what do we do? We starve the poor of these essentials, we allow the fruits and vegetables which contain all that is needed of them to rot on the ground and we seek to remedy our folly by building "vitamin factories" whose products may be every whit as effective as preventives of disease as the natural supplies but which, because they are artificial and therefore expensive, are still less likely to serve the needs of the poorer classes. "Sunbeams out of cucumbers!"

Scientists devote their lives to a study of the passage of shoals of fish from sea to sea in order that the catching of them may be an easier business and that greater quantities may be brought ashore. The catches are landed on the quays. Often, a few hours later, being unsold, they are returned dead to their element again.

To turn from the realm of living matter to that of non-living we find similar absurdities. We dig holes in the earth into which descend many thousands of men seeking, a mile below the surface, amidst the menace of rockfalls and the more insidious danger of silicosis, the rock which, after it has been crushed and chemically treated, will yield immense mounds of waste and a small fraction of yellow gold. Ships carry this across the seas, it is bought and sold, and finally most of it arrives in America where, because it is not really wanted, it is immediately "sterilised" as if it were the germ of some disease (as probably it is) and carefully buried again in fresh holes not quite so deep. We have a glut of gold. All the world really requires is enough to repair its rapidly decaying teeth! The rest may form a monument to the ineptitudes of our economic system "Wherefore spend ye your money on that which is not bread, and your labour on that which satisfieth not?"

Machinery has multiplied the effectiveness of human effort, ten, twenty, a hundred-fold! It has brought little or no corresponding reduction in the daily drudgery of work All the inventions of the past 100 years, while they may have increased our material wealth to an extent undreamt of in 1840, have not abolished starvation and preventible disease. Again to quote Bernal "We have in the world to-day a number of palpable material evils—starvation, disease, slavery and war—evils which in previous times were accepted as part of nature or as the actions of stern or malevolent gods, but which now continue solely because we are tied to out-of-date political and economic systems. There is no longer any technical reason why everyone should not have enough to eat. There is no reason why anyone should do more than three or four hours of disagreeable or monotonous work a day, or why he should be forced, by economic pressure, to do even that. War, in a period of potential plenty and ease for all, is sheer folly and cruelty. The greater part of disease in the world to-day is due directly or indirectly to lack of food and good living conditions. All these are plainly remediable evils and no one can feel that science has been properly applied to human life until they are swept off the face of the earth."

And here is what Mr. Winston Churchill said in 1930 "The root problem of modern world economics is the strange discordance between the consuming and the producing power. Who would have thought that cheap and abundant supplies of all the basic commodities should find the science and civilisation of the world unable to utilise them? Had all our triumphs or research and organisation bequeathed us only a new punishment—the curse of plenty?"

And here is how Mr. Neville Chamberlain as Minister of Health in 1927 described the Welsh coalfields, "Such conditions of destitution are without parallel in the memory of living persons. The devastation in the coalfields can only be compared with the war devastation of France."

In view of all these facts and statements to which numberless others could be added, surely it is time for the scientist and the sociologist both to reassess their contributions to humanity, to consider earnestly the contradictions which face them everywhere, to ask themselves what can be done, how can it be done, and then to "go to it." We cannot delay. We cannot afford, as Sir Josiah Stamp has said, "to call problems 'academic' until we are going under for the third time." The solution is partly political and so, by tradition, cannot be elaborated from a scientific platform. The scientist should however, because of his training in analytical and deductive method, be as well equipped as any to diagnose the ills of society and to suggest remedies; and both he and the sociologist must play their parts in solving some of the present disharmonies between science and society.

No Neutrality.

The great point I wish to impress is that in these matters there can be on the part of the scientist no neutrality. The obstacles to the achievement of plenty are real enough, but they are political and economic, not technical obstacles. Given the will and the understanding they can and must be overcome. We must *demand* that science be allowed to develop, allowed to develop for the benefit and not for the destruction of mankind. If such development cannot find a place in the present social order, our first duty can only be to change that order. It has been done before. Scientists have been amongst the foremost in most social revolutions. Think of Bruno in the Reformation, Galileo with his defiant "Eppur si muove," Priestley who by his support of the cause of revolution in France, called down on his head the wrath of the mob, had his house burnt and his library and apparatus destroyed. These were men who were not afraid to voice their heretical opinions, who were prepared if need be to fight for them, to die for them. To-day science is once again in revolt. It demands a new order. It has the power to create one.

Science misapplied can lead a people into the depths of degradation, it can destroy all that we cherish most in civilisation, it can create mechanised armies of hate and bring again a darkness like that of the middle ages: Science rightly used can usher in an age of plenty, it can abolish war, poverty and disease, it can create such a world order of enlightened freedom and progress that the year 1940 may, by the historian of that future time, be used as the date when the world began to emerge from its second dark age. The responsibility for the future rests both on Society and on Science.

Society must see to it that the fruits of Science are applied to social ends. Science must supply direction and co-ordination to the social advance, for the scientist, at once the product and the servant of a dying culture, holds in his hands the key to the making of a new.

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